POWER

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The N. A. P. E.

THE National Association of Power Engineers, or, as it was known up to a few years ago, the National Association of Stationary Engineers, is approaching its fiftieth birthday.

The convention which it is holding at Cleveland the week of Sept. 8 will be its forty-eighth annual.

At the meeting of the New England States Association at Salem, in June, I sat with James Duncan, one of the few surviving members of the group which initiated it. There lies before me as I write the slip of paper on which he listed the eight previously existing local engineering organizations which were molded into the new national association.

He was a member of the Boston society and is still a member of Boston No. 1, which that society became at the amalgamation.

If there are those still living who were members of any of these constituent organizations they should make it known, in view of the approaching semi-centennial.

The succeeding years have witnessed great changes in power engineering of which the N. A. P. E. is the organized expression; in the power plant engineer of whom it is composed, in the type of plant which he operates, and in the kind of service that is expected of him.

In an increasing degree he has become a department head and is expected to have an intelligent part and interest in the economics of the system under his control.

One of the questions that men in such positions are called upon to answer is when to replace apparatus which is still operative but outclassed by more modern and efficient types.

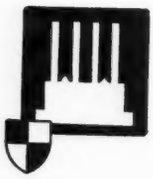
There are many things to be taken into account in a well-considered opinion which will stand analysis by the executives, prove out on application, and win credit for and confidence in the engineer who formulates it.

In the wish to bring to the members of the N. A. P. E. something which should be of especial service in this number of *Power*, which appears at the time of its convention, the subject of maintenance and replacement has been made its theme.

I hope that it may be found useful and that the convention may intelligently point the direction and furnish the inspiration that will carry the association to years of continued progress and usefulness.

F. R. Low

EDITORIAL



Maintenance—Its Economic Importance and Control

THE EVER-PRESENT STRUGGLE to reduce production costs is reflected in the attention being given to economies in power generation. While much has been accomplished through improved efficiencies and the elimination of waste, it is now recognized that maintenance is a factor that cannot be ignored. It is of such importance in many plants that *Power* has seen fit to devote this number to a consideration of its many aspects.

Lack of proper maintenance leads to reduced efficiency, loss due to outage of the individual machine and related equipment, premature replacement, and a lowered morale of the operating force.

In the earlier days power equipment was relatively simple, low speeds were in vogue, and capacities small. With cheap fuel and cheap labor, scant attention was paid to efficiency, and the experienced eye and ear of the operator were relied on to keep the plant running smoothly. A forced shutdown seldom involved great expense.

THE multiplicity, complexity, and interdependence of modern equipment, its capacity, and the severe duty imposed by present-day practice, have completely changed the picture and made it necessary in all well-ordered plants to predicate maintenance on a definite program of which periodic inspection and an adequate system of records form an essential part. In other words, rule-of-thumb methods have given way to a more scientific manner of approach.

Instruments are an indispensable aid in detecting impending trouble and in revealing wear or deterioration through falling off in performance. But it is vital, in turn, that all instruments be maintained in first-class condition; otherwise their indications will be misleading.

Adequate records are necessary to determine the economic life of equipment and to justify expenditures for replacement. Not only must they reveal the history of each machine, but they must also interpret this in dollars and cents to the management. Without such concrete evidence the operating engineer is at a marked disadvantage when making recommendations.

THUS modern practice no longer depends solely upon the physical senses of the operator, but brings to his assistance instruments and systematic records. That is to say, it is a preventive method, embodying the early detection of wear or deterioration and the correction of trouble before it assumes serious proportions. This is the key to low maintenance and good service.

Designs and materials are constantly changing to keep pace with the demands of rapidly advancing practice. It is therefore important to follow closely all improvements in design and materials brought out by the equipment manufacturers with a view to the possibility of taking advantage of them when renewing parts. In this way subsequent maintenance may be lessened and improvement in efficiency or in operation attained.

WHERE TO LOOK for probable wear; designs which experience has shown to produce minimum wear and deterioration for a given service; suggestions for the care and inspection of equipment; and what average maintenance costs may be expected — answers to such questions represent information that the operating engineer and the plant engineer find most helpful.

Also, the operating engineer and the plant superintendent are often confronted with the problem of whether it is more economical to replace old equipment with new than to continue maintaining the old. This problem is usually susceptible of solution along well-defined lines in which the fixed charges on the new equipment, savings through its better efficiency, the cost of maintenance, and the inadequacy of old equipment to meet expected plant growth, must all be weighed.

THESE are some of the questions pertaining to equipment, from coal pile to switchboard, that *Power* has dealt with in this number. Inasmuch as the experience of the individual operator is necessarily limited, it was deemed best to present the subject, with one exception, as a staff product developed from the composite experiences of many plants. To this end, valuable assistance was rendered by a number of central stations, industrial plants and equipment manufacturers—too numerous to list, but to whom we wish to make acknowledgment.

It is hoped that the contents will not only be of help to the engineers who have already inaugurated maintenance programs, but that it will also serve as an inspiration to those who have not.

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POWER *Stands for . .*

1. Making Power When It Should Be Made
2. Buying Power When It Should Be Bought
3. Cheaper Power Through Modern Equipment
4. Easier Financing of Equipment Purchases
5. Better Use of Byproduct Heat and Power
6. Operating Methods That Save Money
7. Less Waste in Transmission and Application
8. Prevention of Smoke, Within Reason

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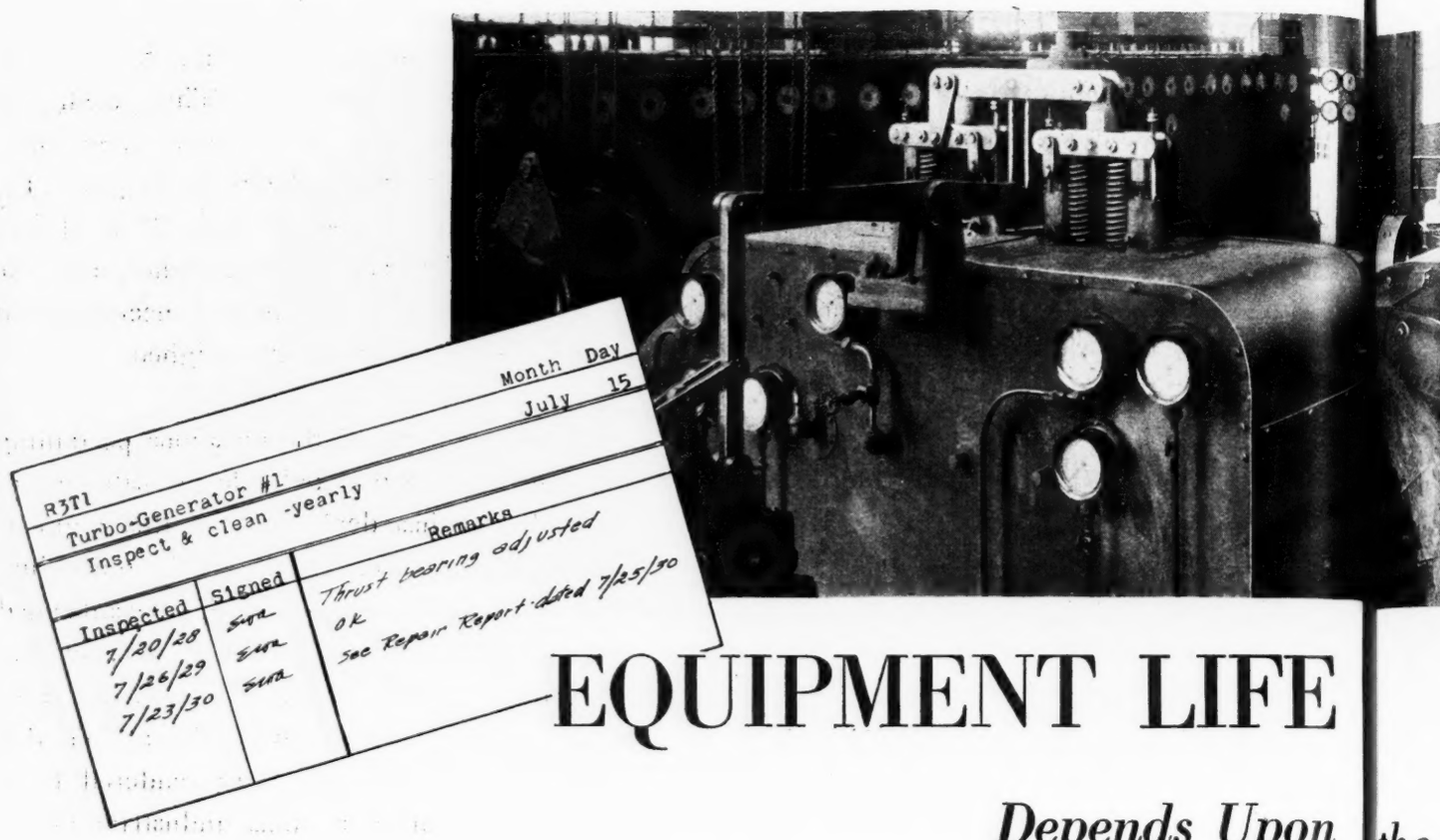


EQUIPMENT LIFE

Depends Upon the

INDUSTRY never knowingly spends, nor should it spend, a dollar for new equipment unless the investment be justified on sound economic grounds. In spite of this, industry is forced to replace existing machinery which if properly maintained would have had its useful life lengthened by five, ten, or even twenty years.

Lack of maintenance seriously affects three factors of vital importance in the determination of total operating costs. These are: Outage, efficiency, and necessity of stand-by equipment.

Outage is serious, whether in a central station or in an industrial plant. Manufacturing often entails an extended and uninterrupted process, in which event the discontinuance of the power supply may prove exceedingly costly, far beyond the mere value of the energy. For example, a flour mill has a continuous process. If power is cut off from the machines it is necessary, before restarting, to clear all the rolls of the partly ground wheat. Even though the outage be for only five minutes, an hour may be lost in clearing the machines.

In an office building the same freedom from power interruption is imperative if the building tenants are to remain. This outage freedom is required of the elevators, light and power system, steam supply, and of all the other engineering activities included in the services expected by the tenant.

Also of importance, although evidence of its presence is often difficult to detect, is the loss of efficiency by reason of failure to properly maintain equipment. While different machines do not show the same characteristics of efficiency loss with wear, nevertheless all machines do suffer from this cause.

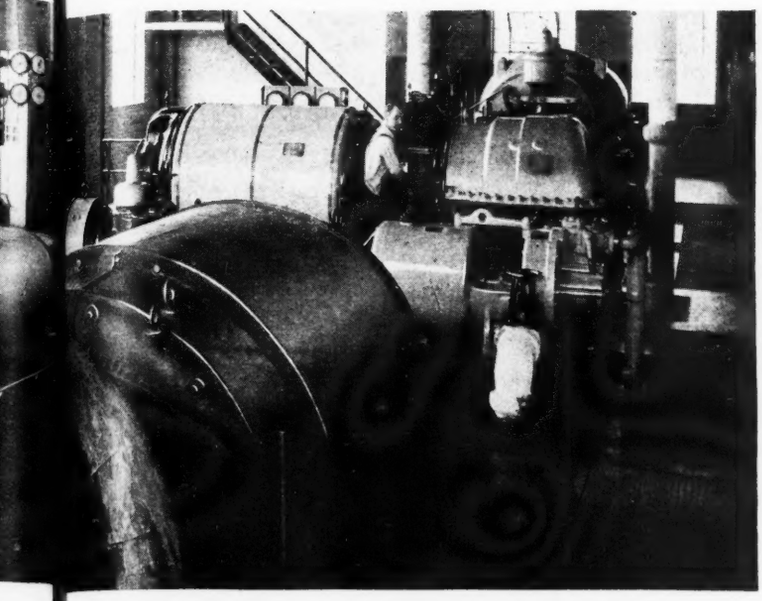
But losses either of volumetric efficiency or mechanical efficiency due to piston ring leakage, misadjusted piston-rod packing, worn shaft bearings, or defective valve gearing can all be eliminated, and, in fact, avoided, by following a regular maintenance schedule.

Lack of regular maintenance and inspection may cause a shutdown at a time when the capacity of the equipment can ill be spared. This situation places a greater burden on other equipment in the plant, making it necessary to operate it at higher rating, entailing a decrease in economy. Another result of this condition, the value of which would be difficult to estimate, is that sometimes the remaining equipment is unable to carry the full plant load, necessitating curtailment of production.

A more insidious effect of poor maintenance is its lowering of operating morale. For example, a fireman who may be ambitious to maintain the best combustion conditions soon loses his enthusiasm when he finds his efforts are hindered by poor stoker repair, which makes it impossible for him to maintain an even fire bed.

When deferred maintenance on old equipment has seriously impaired its efficiency, two courses are open—money may be appropriated for the work necessary to place the machine in such condition that its original efficiency can again be obtained, or an appropriation made for the purchase of a new equipment whose efficiency is equal to or better than that obtainable if the old machine were repaired.

To determine which is the better proposition, clear



Of greatest importance, although evidence of its presence is often difficult to detect, is the loss of efficiency by reason of failure to properly maintain the equipment. While machine types do not show the same characteristic of efficiency loss with wear, nevertheless, all machines do suffer from this cause

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the MAINTENANCE PROGRAM

thinking and shrewd engineering judgment are necessary. The average load and the number of hours that the machine will be in operation must first be assumed. If from this time on the equipment is kept in good operating condition, the yearly saving resulting from reconditioning will continue until such time as this machine becomes inadequate for its present service, or the improvement in efficiency of other similar equipment justifies its replacement.

This yearly saving, it may be assumed, could be placed at compound interest, and during the remaining life of the machine would accrue to a certain sum. The *present worth* of this sum is that amount which if invested at compound interest would equal at the end of the life of the machine, the sum resulting from the yearly savings. The present worth is the amount that may justifiably be spent for maintenance—but certainly not more than that should be appropriated.

If the actual cost of reconditioning equipment is less than the allowable cost indicated by the savings in operation, maintenance work would be justifiable, and the difference between the two is the incentive. The difference or incentive divided by the estimated maintenance cost is the incentive per dollar of expenditure, or the *incentive factor*.

Presumably, it would be possible to replace the old unit with a new one whose efficiency or operating cost would be less than the operating cost of the reconditioned old machine. The yearly saving in operating cost of the new over the operating cost of the unreconditioned machine must be determined for the same load conditions as in the case of the old one. This operating saving would continue during the life of the old machine, and can be also considered as being placed at compound interest. The present worth of this annual saving during the life of the old machine represents what can be paid for new equipment compared to operating the old machine in its present condi-

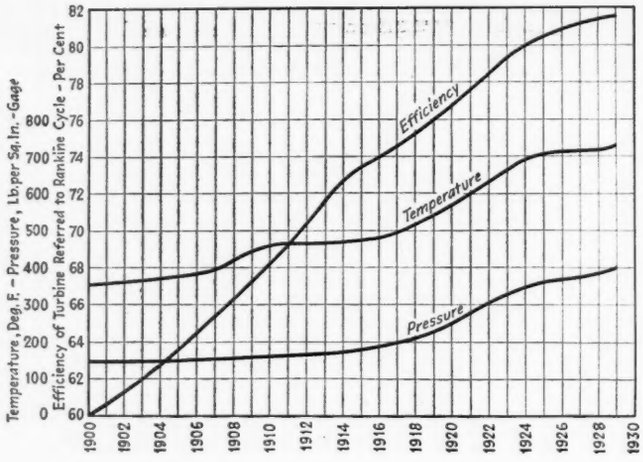


Fig. 1—Yearly increase in turbine efficiency

the future may be inferred from the curves of Figs. 1 to 3, which indicate the past trends in efficiency of various pieces of power plant equipment and of power plants as a whole. While it is true that these do not accurately foretell anything in regard to the future, it is, nevertheless, not unreasonable to extend these curves into the future by reference to their past and present trends. It may be that the improvement in efficiency indicated by the curves of any one particular piece of equipment will show that the reconditioned unit will still have a considerably longer life, from an efficiency viewpoint, than originally expected. In this case the life of the equipment may perhaps be more reasonably indicated by the trend of the curve showing efficiency of the power plant as a whole. The slope of this curve is somewhat steeper than that for the individual unit, because of changes in steam temperature and pressure, and this may indicate a sufficient saving for a complete replacement of the old plant at a time prior to the life indicated by a consideration of the improvements in efficiency of only one machine.

TABLE I—FACTOR *V* USED IN FINDING TOTAL AMOUNT OF ANNUAL SAVING FOR THE MACHINE LIFE

Years	r = 2	2½	3	3½	4	4½	5	6	7
1	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000	1 0000
2	2 0200	2.0250	2.0300	2.0350	2.0400	2 0450	2 0500	2 0600	2.0700
3	3.0604	3.0756	3.0909	3 1062	3 1216	3 1370	3 1525	3 1836	3 2149
4	4.1216	4.1525	4.1836	4.2149	4.2465	4.2782	4.3101	4.3746	4.4399
5	5.2040	5.2563	5.3091	5.3625	5.4163	5.4707	5 5256	5.6371	5.7507
6	6.3081	6.3877	6.4684	6.5502	6.6330	6.7169	6.8019	6.9753	7 1533
7	7.4343	7.5474	7.6625	7.7794	7.8983	8.0192	8.1420	8.3938	8.6540
8	8.5830	8.7361	8.8923	9.0517	9.2142	9.3800	9 5491	9.8975	10.260
9	9.7546	9.9545	10.159	10.368	10.583	10.802	11.027	11 491	11.978
10	10.950	11.203	11.464	11.731	12.006	12.288	12.578	13.181	13.816
11	12.169	12.483	12.808	13.142	13 486	13.841	14.207	14.972	15 784
12	13.412	13.796	14.192	14.602	15.026	15 464	15.917	16.870	17.888
13	14.680	15.140	15.618	16 113	16.627	17 160	17.713	18.882	20 141
14	15.974	16.519	17.086	17.677	18.292	18.932	19.599	21.015	22.550
15	17.293	17.932	18.599	19.296	20 024	20.784	21.579	23.276	25 129
16	18.639	19.380	20 157	20.971	21.825	22.719	23.657	25.673	27.888
17	20.012	20.865	21.762	22.705	23.698	24.742	25.840	28.213	30.840
18	21.412	22.386	23.414	24.500	25.645	26.855	28.132	30.906	33.999
19	22.841	23.946	25.117	26.357	27.671	29.064	30.539	33.760	37.379
20	24.297	25.545	26.870	28.280	29 778	31.371	33.066	36.786	40.995
25	32.030	34.158	36.459	38.950	41.646	44.565	47.727	54.865	63.249
30	40.568	43.903	47.575	51.623	56.085	61.007	66.439	79.058	94.461
40	60.402	67.403	75.401	84.550	95.026	107.03	120 80	154.76	199 64
50	84.579	97.484	112.80	131.00	152.67	178.50	209.35	290.34	406.53
60	114.05	135.99	163.05	196.52	237 99	289 50	353 58	533.13	813 52

tion. Whether the maintenance work shall be done, or new machines installed, is indicated by the relative value of the incentive factor. Another factor is the interest rate that these proceedings give on the difference between the present worth of the saving and the cost of the equipment. Obviously, even though reconditioning gave a greater incentive factor, which means a greater per cent return on the incentive, still the return on the incentive of the new-machine purchase might be so much above the current rate of interest that the new machine would be the more attractive proposition.

One of the determining factors in the calculations is the prediction of the probable future life of the old equipment. This should not be left to the accountant, who makes a somewhat haphazard guess or uses traditional values, which, while satisfactory for accounting purposes, fails to meet the engineering criterion of accuracy.

Predicting future useful life calls for engineering judgment that takes into consideration the characteristics of the particular machine considered together with the present-day trend of power plant equipment design.

The question of when the machine will again wear out does not enter the problem, as this occurrence only involves another major maintenance expense. The future useful life of the old equipment is rather determined by a consideration of the number of years it will still be adequate for performing the service required of it. It is also influenced by the development of more efficient equipment.

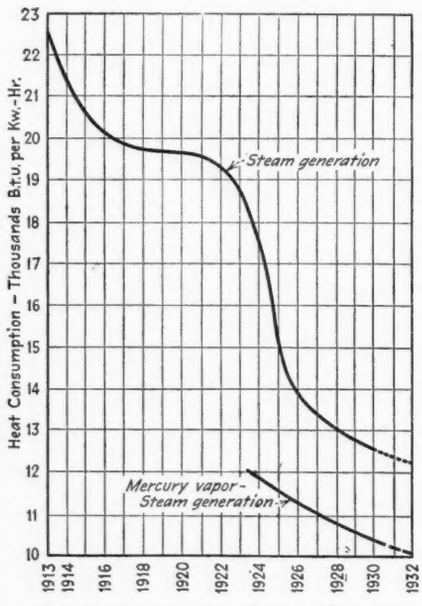


Fig. 2—Increase in plant performance since 1913

Some help in determining the probable improvement in economy that may be expected of a new machine in

Considering whether the old equipment will be adequate for service in the future, a number of questions come up. For example, it may be that the load on a present boiler plant is expected to increase with the increase in business. Thus, ten years hence the management may be faced with the question of whether to extend the boiler house building to permit the installation of additional new boilers, or to replace the old boilers with new units capable of operation at higher rating without changing the present building. This, of course, involves the question: Will it be cheaper, at the end of ten years, to extend the boiler house sufficiently to house new boilers, or will the present boiler be sufficiently obsolete at that time to make the installation of a new boiler desirable, particularly in view of its decreased capacity?

To illustrate the procedure of establishing the comparative values of reconditioning old and of purchasing modern equipment, let us take a plant that contains two 5,000-sq.ft. boilers. These are fitted with underfeed stokers, which are in need of repair to such an extent that the original boiler efficiency has dropped from 70 per cent to 65 per cent. The plungers and retorts are badly worn, some of the tuyères are burned out, and the secondary rams are so worn that the fuel bed agitation is poor.

The stoker manufacturer offers to recondition the two stokers for $5,600, which he guarantees will bring the efficiency back to 70 per cent. New stokers, provided with two-speed gears and improved dumping attachments, will give 76 per cent efficiency, but will cost $15,000.

The problem then is: Which is the better proposition?

TABLE II—FACTORS FOR OBTAINING PRESENT WORTH OF A SERIES OF ANNUAL SAVINGS

Years	r = 2	2½	3	3½	4	4½	5	6	7
1	.98039	.97561	.97087	.96618	.96154	.95694	.95238	.94340	.93458
2	.96117	.95181	.94260	.93351	.92456	.91573	.90703	.89000	.87344
3	.94232	.92860	.91514	.90194	.88900	.87630	.86384	.83962	.81630
4	.92385	.90595	.88849	.87144	.85480	.83856	.82270	.79209	.76290
5	.90573	.88385	.86261	.84197	.82193	.80245	.78353	.74726	.71299
6	.88797	.86230	.83748	.81350	.79031	.76790	.74622	.70496	.66634
7	.87056	.84127	.81309	.78599	.75992	.73483	.71068	.66506	.62275
8	.85349	.82075	.78941	.75941	.73069	.70319	.67684	.62741	.58201
9	.83676	.80073	.76642	.73373	.70259	.67290	.64461	.59190	.54393
10	.82035	.78120	.74409	.70892	.67556	.64393	.61391	.55839	.50835
11	.80426	.76214	.72242	.68495	.64958	.61620	.58468	.52679	.47509
12	.78849	.74356	.70138	.66178	.62460	.58966	.55684	.49697	.44401
13	.77303	.72542	.68095	.63940	.60057	.56427	.53032	.46884	.41496
14	.75788	.70773	.66112	.61778	.57748	.53997	.50507	.44230	.38783
15	.74301	.69047	.64186	.59689	.55526	.51672	.48102	.41727	.36245
16	.72845	.67362	.62317	.57671	.53391	.49447	.45811	.39365	.33873
17	.71416	.65720	.60502	.55720	.51337	.47318	.43630	.37136	.31657
18	.70016	.64117	.58739	.53836	.49363	.45280	.41552	.35034	.29586
19	.68643	.62553	.57029	.52016	.47464	.43330	.39573	.33051	.27651
20	.67297	.61027	.55368	.50257	.45639	.41464	.37689	.31180	.25842
25	.60953	.53939	.47761	.42315	.37512	.33273	.29530	.23300	.18425
30	.55207	.47674	.41199	.35628	.30832	.26700	.23138	.17411	.13137
40	.45289	.37243	.30656	.25257	.20829	.17193	.14205	.09722	.06678
50	.37153	.29094	.22811	.17905	.14071	.11071	.08720	.05429	.03395
60	.30478	.22728	.16973	.12693	.09506	.07129	.05354	.03031	.01726

The boilers are operated 54 hr. a week, and at present the yearly coal bill is $40,500. Reconditioning will raise the efficiency from 65 to 70 per cent, thereby reducing the coal bill to $37,607, an annual saving of $2,893.

As the boilers may need to be replaced in ten years, it is advisable to assume this to be the additional life to expect of the stokers.

Annual savings of $2,893 for ten years placed at 6 per cent compound interest will amount to a sum which is equal to AV, where A is the annual saving and V a factor found under 6 in the per cent interest column opposite ten years' life in Table I. It will be seen that V is 13.181. The total value of the savings is then $2,893 \times 13.181 = \$38,132$.

Now the value of the reconditioning is the *present worth* of this sum, or the amount of money which placed at interest today will amount to $38,132 in ten years. To find this present worth, turn to Table II, and under 6 in the r, per cent interest, column and opposite 10 in the year column will be found the factor 0.55839. The given sum multiplied by this factor gives the present worth, or $38,132 \times 0.55839 = \$21,292$.

Next let us consider the new stoker proposition: If the efficiency is to be 76 per cent, the yearly coal cost will be $65/76 \times 40,500 = \$34,638$. This is a saving of $\$40,500 - \$34,638 = \$5,862$, compared with present-day costs. These annual savings in ten years will total $77,267, and the present worth of this sum is $\$77,367 \times 0.55839 = \$43,145$.

In both instances, the present worth of the procedure is so much greater than the investment that the interest rate obtained is far above the current one. The management and the engineer must then decide which offers the greater incentive in view of the financial position and earning rate of the factory. Under ordinary conditions the new stokers should be the more attractive proposition.

In many power plants the machinery does not wear out or become obsolete because of deferred maintenance. Power plant equipment is usually discarded due to obsolescence, or decrease in usefulness due to the existence of more efficient machinery. The approach to the problem of discarding old equipment is the same as outlined heretofore.

There is, however, the factor of machine life, which, if not properly chosen, will seriously and adversely affect the answer obtained.

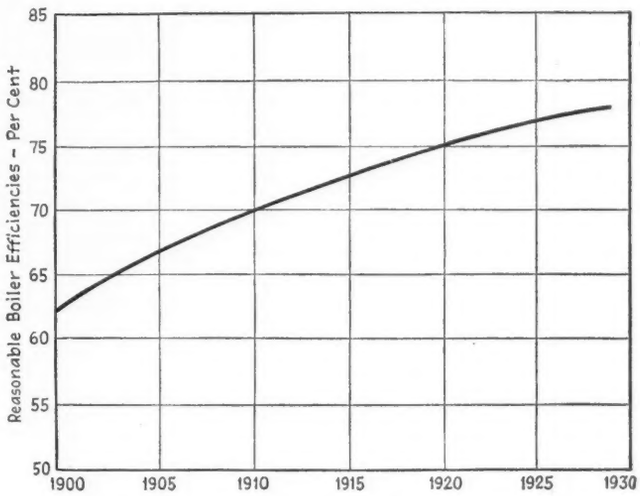
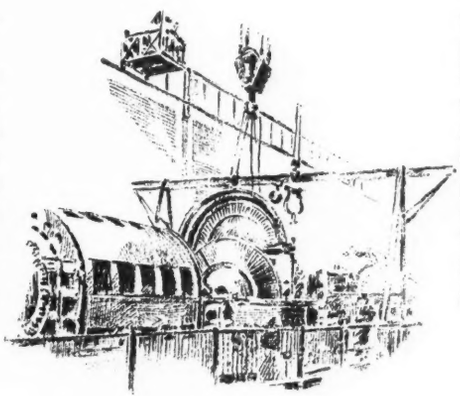


Fig. 3—Boiler efficiencies obtainable in industrial plants

Power plant equipment has experienced certain definite periods of improvements in designs, followed by a more or less static period. Examination of the several efficiency curves reproduced in this article will reveal that no decided increase in turbine or boiler efficiency can be expected for some time. While a plant installed ten years ago might be inefficient compared to a plant built today, the same will not be true of plants built today, as inspection of the efficiency curves will reveal. Consequently, one at this date can safely give a plant or a piece of plant equipment a longer life than it was safe to give it ten years ago. This means that the present-day buyer of machinery need have no fear of excessive obsolescence.



Establishing a Maintenance Cost System

By STUART W. ALLEN
Plant Engineer,
Sayles Finishing Plants

While the subject of power plant maintenance is separate and distinct from operating, it is, nevertheless, closely tied in with it in its practical application, and it is generally advisable to devise some system for collecting and tabulating all data applicable to both problems

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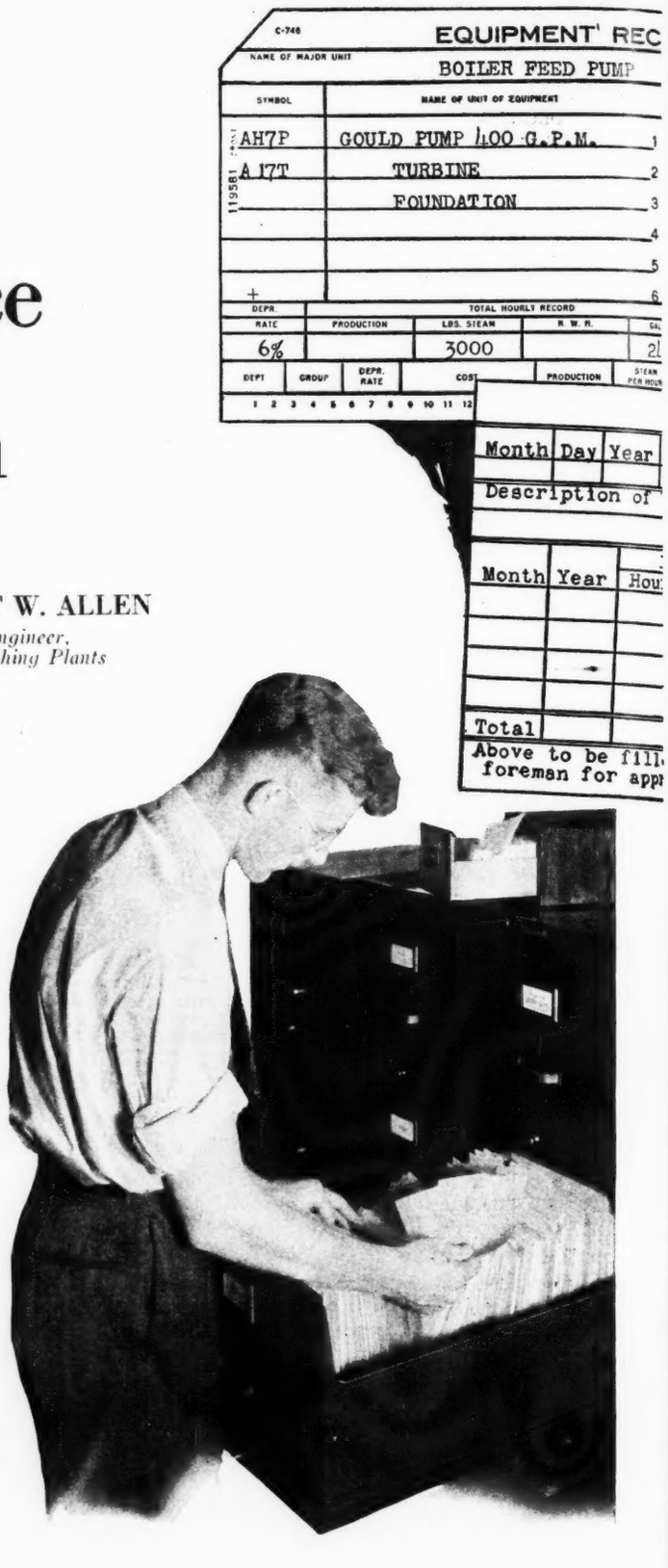
RAPID DEVELOPMENT in power plant equipment and continual changes in the design of the plant itself, whether central station or industrial, have, in the last few years, evolved various methods of scheduling maintenance work and of recording maintenance and operating data and costs. Without such records it would be impossible to determine the economic life of equipment or to justify expenditures for modernization.

The chief engineer of a power plant must be more than a mere operating mechanic; he must be an executive and must have at his finger tips knowledge of the present condition of all equipment in his charge and sufficient data for him to estimate closely the future life of, and probable repairs to, this equipment. This means that he must be something of a prophet as well. He cannot carry excessive stand-by equipment and neither can he chance a possible shutdown from machine failure. His task would be almost hopeless were it not for the fact that it is possible by regular inspections and by the proper recording of repairs to set up a log from which a fairly reliable prophecy of future operation can be determined.

This is not as complicated as it may sound, and most engineers have their own methods of obtaining these facts. However, some simple rules and suggestions which it is hoped will be of use to operating men in the average plant are given here.



The first problem of plant maintenance is to make sure that all equipment is inspected at proper intervals, and that a record is kept of these inspections, with notes available of all repairs made. It is essential, therefore, that an inspection routine be developed and that it be strictly adhered to.

After a schedule of inspection has been developed, some method of maintaining the system must be decided

ORD

DEPT. NO. 29
PROCESS 3
GROUP NO. 6

MAKER	ORDER DATE	ORDER NUMBER	COST
GOULDS MFG CO	6/6/28	785Y	2000 00
WESTINGHOUSE			
MECHANICAL			350 00

FACTOR PER UNIT OF CLOTH

S WATER	STEAM	K. W. H.	WATER	2350 00
4000				

K. W. H.	WATER GALS. PER HR.	STEAM FACTOR	K. W. H. FACTOR	WATER FACTOR

Fig. 1—An equipment record is of advantage if maintenance costs are to be analyzed

Fig. 2—Type of repair order card used

REPAIR ORDER

Charge Symbol | Job No.

Work to be done:

Labor rs Wages	Shop Expense	Stores	Total Cost

ed in before giving to oval.

Signature of man placing order

This job has been completed to my satisfaction.
Sighed
Date

To be signed by foreman in charge of department where work was done.

upon. Probably the simplest method for the average plant is the "tickler" system, in which a card is made out for each piece of equipment, with the date of inspection marked at the top; a sample of such a card, as used in a large industrial plant, is shown in Fig. 3.

Three columns are ordinarily made on these cards. In the first column is entered the date when the inspection is actually completed; this, of course, seldom agrees with the date at the top of the card, as that date is merely a request to do the work at about that time. In the next column is the signature of the man responsible for the inspection; in some cases two columns are left for signatures. The remaining column is used to show the condition in which the machine was found or to state briefly the work done.

In case of extensive repairs, it is generally advisable to make a full report of the work done, in which case this report is filed separately in a report file and the tickler card then carries a notation as to the date of the report.

Tickler cards are generally filed in the chief engineer's office. A small drawer file or box can be used for that purpose. Division cards are placed in the file with the tabs marked for the months of the year, and the tickler cards are placed in this file in order of dates. At the end of each month, that period's division card and the cards under it are placed in the back of the file, causing the current month's cards always to be in front, where they are readily accessible. The chief engineer should make it a regular practice to check the tickler file the first thing each morning to determine what routine matters are scheduled for that day.

When extensive repairs are made, a report should be written giving their general scope. It need not be filled in on a particular form, but is generally written on regular 8½x11 letter-size paper and filed in a standard letter file. This report should be headed by the date the repairs were made and state the machine involved. An outline of such length as the chief engineer deems advisable should be made, describing the work performed, the reasons for the work, and the condition of the equipment after completion. These reports should be filed under the names or symbols of the equipment and should be placed in order of their dates.

By making use of the foregoing records it is possible to gage the average frequency of repairs for each piece of equipment and to determine if these repairs are becoming too frequent, and whether the equipment is standing up as well as expected. With this knowledge, it is possible to decide on the amount of repair parts or stand-by equipment that it is necessary to maintain at all times, and it is therefore possible also to cut this and the resulting fixed charges to a minimum and at the same time maintain an operating condition reasonably safe from shutdowns.

After having developed a method for keeping his equipment in good operating condition and minimizing the possibility of shutdowns, the chief has still another problem confronting him, namely, the keeping of reliable records showing the cost of maintaining his equipment as well as his regular operating costs. As the subject of operating expense is one generally taken care of by the accounting department and is a problem apart from maintenance, it is not discussed here. The proper allocation of repair costs, however, is a point that is not taken care of in the average plant, and is of great interest to the operating force. As the management views all problems from the dollars-and-cents angle, all questions of repairs or replacements must be placed before them in this language.

Because the accounting department is in most cases already taking care of all expense items, any system for breaking down this expense and allocating it to certain machines or departments must work in with the general accounting method. It is therefore impossible to set down any fixed rules for handling this problem, but the method given below has been used with considerable

R3T1 — Month Day

Turbo-Generator #1 — July 15

Inspect & clean -yearly

Inspected	Signed	Remarks
7/20/28	Sua	Thrust bearing adjusted
7/26/29	Sua	OK
7/23/30	Sua	See Repair Report dated 7/25/30

Fig. 3—Inspection tickler card used in one plant

success in a number of plants. Regardless of the system followed, however, the results must conform in general with those obtained from this system if the full benefit of the accounting effort is to be received.

To provide for proper distribution of expense it is necessary to maintain some system of identification for machines and departments. The word "department" is used here to indicate a general classification, such as coal storage and reclaiming, steam generation, power generation, machine shop, etc. To accomplish this end some

method of symbolization is ordinarily employed. One that has been successfully employed in several instances is as follows:

The power plant is given some general distinguishing classification, such as the letter *R*. Any symbol beginning with *R* then refers only to the power plant. Each department is then given its identifying number or letter. The steam-generating plant, for instance, may be designated by the figure *2*. Any equipment, therefore, in the boiler house of this plant would be designated by the symbol *R2*. Each type of equipment is then given its identifying mark; the boilers, for example, may be listed under the classification *B*, the number of the particular equipment following this general classification. The symbol for No. 5 boiler in this plant would, therefore, be *R2B5*. Equipment attached to a boiler can be identified, if desired, by adding to the symbol, as, *R2B5D*, representing the damper of No. 5 boiler.

Turbine-generator No. 1 in this plant would probably be given the symbol *R3T1*, the "*3*" representing the

STORES CARD

Month	Day	Year	Job No.	Symbol

Quantity

Description

Unit Price | Total Value

Condition O.K.-Signed by Man Ordering

Above stores have been issued

Storekeeper

Fig. 4—Card used to draw out stores

operation of power generation. This symbol is given on the tickler card illustrated to indicate that turbine-generator No. 1 is referred to on that card.

In the case of equipment which it is impossible to symbolize individually, general classifications are given, such as *F*—Furniture and Fixtures; *M*—Machinery; *T*—Tools; *H*—High-Pressure Piping, etc. The method of symbolization must be worked out to meet the individual requirements. No fixed rule can be set that will apply with equal success to all plants.

Some prefer to use numerals rather than letters. The system of alternate letters and figures as illustrated, however, is generally easier to follow, particularly for the man employed in the average power plant, who must make use of these symbols.

Stores cards are issued to cover all material and supplies used in the plant, being marked with the symbol of the machine or department against which the charge is to be made. A typical card appears in Fig. 4. These should be signed only by the person in charge of the department that is being billed, and that person should be responsible for seeing that the proper symbols are marked and that the charge is correctly entered. In many cases this man is responsible only to the extent of stating that the material has been received in good condition and that it is being charged against the proper department. The value of the material is entered by the clerk in charge of the stores department, or by someone designated for the purpose.

Labor must also be charged in a manner somewhat similar to that employed for stores. The time card, Fig. 5, is ordinarily the basis of charging labor, and it should give the man's identifying number and the symbol against which his labor should be charged. One method that has proved successful in a number of plants involves a man's taking out a new time card each time his occupation so changes that his labor is to be charged against a different symbol. Plant conditions, however, may make it inadvisable or impracticable for a man to change his card with each change in occupation; then a single card may be used, with the hours spent on each job marked on it.

For maintenance or repair work the labor charge is ordinarily made against the individual machine, while for general operation the charge is generally made against a classification in a department, such as firing, coal handling, cleaning, etc.

In addition to the above labor expense which is covered by time cards, there are the items of salaries and general expense. Salaries cover that portion of the payroll expense not covered by time cards and includes not only those persons who are directly chargeable to the power plant, but also a definite proportion of executives' time.

General expense covers all items of general office expenses which are not directly chargeable to any de-

TIME CARD

Mon.	Day	Year	Job No.	Symbol

Name	Number	Craft

Time Start	Time Finished	Time Consumed

Regular Time	Overtime	Total Time

Rate	Wages	O.K.-Foreman

Fig. 5—Labor time is kept on this card

partment, a definite proportion of which are charged against the power plant. These items are usually split arbitrarily among the various departments.

It is rather common practice in the case of repair labor to charge the direct labor employed, plus a percentage to cover salaries and general expense as noted above. This percentage may vary from time to time, and it is therefore advisable to revise the figures at regular intervals.

The most elaborate system of cost gathering would be valueless without some simple method of making use of the figures obtained. This requires, first, that they be automatically brought to the attention of the persons interested, and, secondly, that they be in such form that their story is told at first glance. The chief engineer who has this information readily at hand is always able to bring his recommendations forcibly to the attention of the management and in this way keep his plant in the best condition, hold expenses to the minimum and save labor both for himself and the men under his direction. This places him in a most favorable position in the eyes of the management and generally works to his material benefit.

In some plants a complete equipment record is kept, together with all repair and replacement costs. One

method of handling this problem is to make out a card for each piece of equipment. This card, Fig. 1, is generally filled in with the name of the machine, the symbol of the department in which the machine is located and the symbol of the machine itself. The maker's name is given, and it is usually advantageous to give the order number and date on which the machine was purchased. This offers a ready reference to the order and all correspondence relative to the purchase of the machine.

REPAIR ORDER

Month	Day	Year	Charge Symbol	Order No.

Description of work to be done:

Month	Year	Labor Hours	Labor Wages	Shop Expense	Stores	Total Cost
Total						

Above to be filled in before giving to foreman for approval.

Signature of man placing order

This job has been completed to my satisfaction.
Signed _____
Date _____
To be signed by foreman in charge of Dept. where work was done.

Fig. 6—A typical repair order card issued to the man who is to do the work

Purchase price of the equipment is also generally entered on this card. In many cases it has been found of advantage to note the rate of depreciation and other important information regarding the equipment.

The back of this card is generally ruled to give the order number, date, and cost of repairs or replacements to the equipment covered by the card. When a repair job is closed the accounting department should furnish the chief engineer with the total cost of the job, and he should enter this information on the back of the equipment record card. In this way be will always have available information regarding each piece of equipment under his supervision. If he finds that repair costs have mounted to a point where they are greater than the fixed charges on the equipment, he has a definite argument for replacing that particular machine. These figures may also show him that operating conditions have changed, that the repairs were not properly made, or that some change in the design would be advantageous.

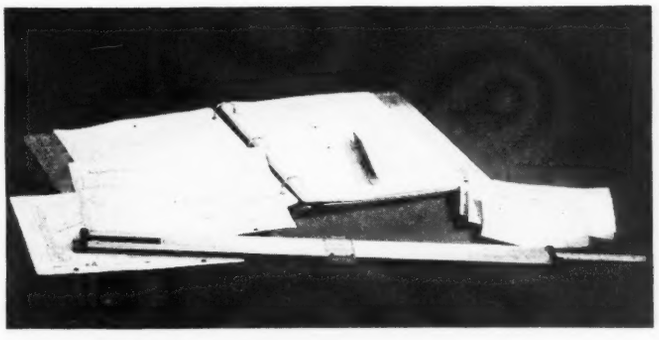
The most careful cost gathering and tabulation possible will be of little benefit if the principal facts are not constantly being presented to view. In a great many plants considerable time and effort is spent in gathering data and making records that are filed away and never repay the cost of obtaining them. For this reason it seems advisable to present at regular intervals, preferably monthly, a brief résumé of maintenance expense. This can easily be combined with the regular monthly operating figures so that any variation is immediately noticed. Ready visibility and continual check-up are main features of any standardized method of maintenance.

A form of monthly report for each department which combines in brief form the principal items of fixed charges, operating expense, repairs, and auxiliary charges, together with unit costs, should be made up. A form of this kind was originated for an industrial plant, and a single sheet is used for each six months' period. The total for this period is compared with the previous six months' total and also with the previous year's. As the plant for which this sheet was designed has budgetary control, a stint, or estimated allowance, is entered and compared with the actual figures. It is thus readily seen whether the costs are running above or below the estimate.

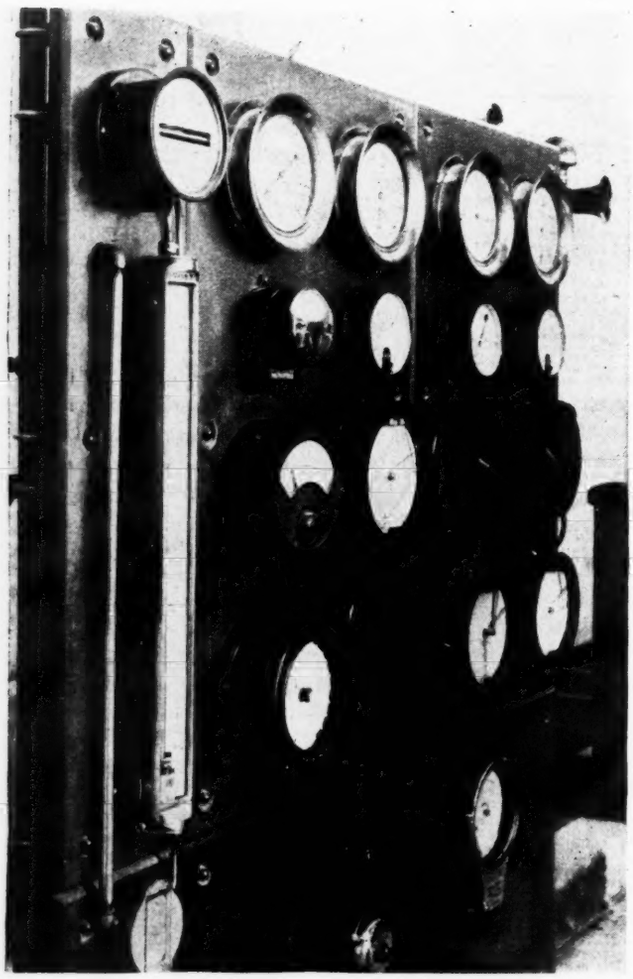
A report of this type must be a part of the plant's regular accounting system, but if given to the chief engineer monthly he is able to follow his costs closely and, when a rise in costs is noted, immediately check back through his other records to determine the cause of this change. The report in this sense acts merely as a tickler, reminding the chief to make use of the available records when costs are varying from their natural course. It will be noted that this report is applicable to both maintenance and general operating problems. It is in reality a monthly trial balance for comparison with previous balances to show the general trend.

It must be remembered that a power plant is, to all intents and purposes, a complete business enterprise, and that, following the trend of modern business, proper gathering, tabulating, and use of data are essential. Opinions are of little value unless backed up with facts, and the easiest and most practical method of obtaining these facts is by systematic use of records. This does not necessarily mean that any complicated system must be installed or an army of clerks hired, but merely that a few simple forms be properly kept and the information checked periodically.

That many operating engineers are unable to sell their ideas to the management is simply due to the fact that the technical engineer and the business man do not normally talk the same language. If the power plant man will tabulate his records and prepare his cost estimates in accordance with modern business methods as suggests here, experience has proved that the management will generally understand the arguments of the technical man much more easily, and in the majority of cases will agree, in principle at least, with the request. In this way the power plant engineer sells himself and his ideas to his superiors to the benefit of all concerned.



INSTRUMENTS in GOOD REPAIR



Unlike other equipment, lack of maintenance not only affects the instrument, but also influences the efficient and reliable operation of the entire plant. An inaccurate instrument is often worse than none

METERS and instruments installed in power plants may be broadly classed under two headings: First, those necessary for plant operation, and, secondly, those required only for improving station economy. In the first class fall such instruments as the steam pressure gages on the boiler and those indicating feed-water pressure at the pump and at the boiler, gages on the turbine indicating oil pressure, vacuum gages for the condenser, and draft gages for the boilers. Without these instruments operation would be almost impossible, or, to say the least, hazardous. The second classification consists of thermometers and pressure gages necessary to the operators for maintaining high economy, or necessary to the technical staff of the plant for calculating station performance.

Failure or inaccuracies of those instruments falling under the classification of those necessary for operation will result in difficulties. Suppose something happened to the pressure gage on the boiler feed pump that caused it to indicate pressures higher than actually existed. The operator, endeavoring to regulate his pump to a prescribed pressure, would reduce the pressure on the pump to bring the gage back to that pressure which he had been directed to maintain. This would result in the actual pressure dropping below that necessary to deliver water to the boiler. But little imagination is needed to picture the results. Hence the instruments of this classification should receive greater attention than any of the other instruments in the plant. They should be gone over thoroughly at least once a month, and their accuracy carefully checked. This represents a minimum of inspection, for it may be that because of operating conditions some instruments falling in this class actually require more frequent inspection.

Failure or inaccuracy of those instruments necessary only for maintaining efficient operation would not be accompanied by such serious consequences. The most that could happen would be a loss in station economy. Such loss, however, will justify a regular routine inspection of these instruments. But such an inspection need not necessarily be as frequent as required for the instruments of the first classification.

The period of routine inspection for instruments found in this latter class should be governed more by past experience with them, rather than by any definite set rule. For this purpose it is desirable, especially in the larger plant, to keep an accurate record of test data and the amount of calibration necessary on all instruments. By doing this, it is possible to determine not only whether the instrument is holding its calibration, but also to determine how often a check should be made. It is not well to trust to memory as to the fittness of any gage, especially over a long period of time.

The amount of maintenance required on instruments is governed by the character of the service under which they operate. For example, a pressure gage used where the pressure is fluctuating, as is frequently the case with hot-well pump service, will require far more maintenance than a gage measuring a steady pressure. It is possible to regulate, to some extent, the amount of maintenance on a gage by its selection. The range of a gage should be such that the point at which it operates does

HELP STATION ECONOMY

not exceed three-fourths of the total scale. It will be found that an ordinary racks and pinions on gages used to measure fluctuating pressure wear out with considerable rapidity. Such movements should be replaced by hardened bronze gears and pinions, which will resist wear and last for a somewhat longer time.

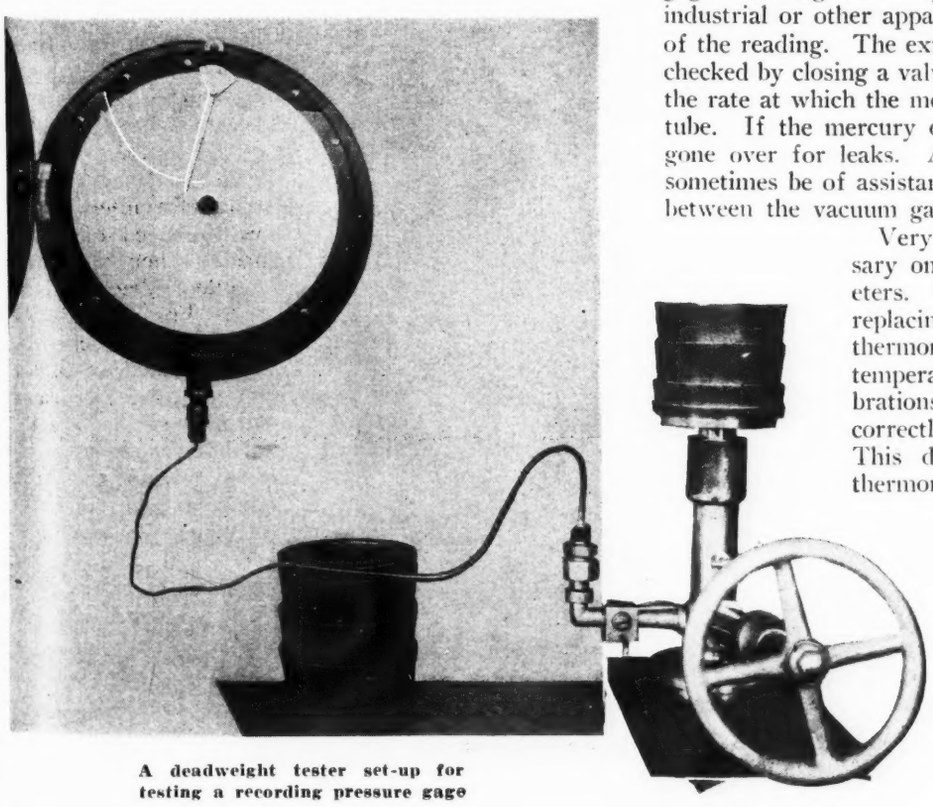
When measuring a fluctuating pressure, the constant flexures of the material of which the Bourdon tube or helix is constructed may result in fatigue of the material. It will be found that gages used on such service will eventually read high, and it becomes necessary to recalibrate them.

If pressure fluctuations are not too severe an instrument can often be protected against them by providing a dampening device in the connection between the meter and the point at which the pressure is being measured. It is not recommended that pressure fluctuations be dampened by throttling the value in the gage connection. A device that has been used in some plants consists of a short piece of $\frac{1}{4}$-in. pipe with both ends plugged and with a $\frac{1}{64}$-in. orifice drilled through the plugs.

Pressure gases should be suitably protected in order that the temperature of the fluid being measured does not affect the internal mechanism of the gage. Gages are designed to operate at a temperature not exceeding 100 deg. F., and the introduction of steam or excessively hot water into the inner tube of a gage will affect its calibration.

It is best to make a systematic test of all pressure gages at least once a month. There are two ways in which this checking can be done. The gage can be removed from service and calibrated against a deadweight pressure. This must be done if it is desired to check the gage over its entire range. With this method allowance must be made for difference in elevation between the gage and the point at which pressure is to be measured. Another method is to use a standard test gage which has been calibrated against deadweight pressure, connecting the calibrated test gage in parallel with the gage to be tested. A comparison of the readings can then be made and the calibration of the operating gage changed. If the test gage is connected in parallel with the operating gage at the point where connection is made to the steam or water line, allowance for difference in elevation between the operating gage and the point at which the pressure is measured is automatically made.

Vacuum gages, as a rule, measure a nearly constant pressure; hence maintenance on a Bourdon tube vacuum gage will be much less than required on a pressure gage. The glass mercury column also will require practically no maintenance. Either type may be checked by placing a mercury glass U-tube in parallel with the operating gage. Leakage in the piping connecting the gage with industrial or other apparatus will influence the accuracy of the reading. The extent of this leakage can easily be checked by closing a valve at the condenser and watching the rate at which the mercury column drops in the glass tube. If the mercury drops rapidly the line should be gone over for leaks. A candle or kerosene torch will sometimes be of assistance in finding leaks in the piping between the vacuum gage and the condenser.



A deadweight tester set-up for testing a recording pressure gage

Very little maintenance work is necessary on commercial mercury thermometers. It for the most part consists of replacing broken glass fronts. Mercury thermometers used to measure moderate temperatures generally hold their calibrations for a long period and when once correctly set need not again be touched. This does not, in general, hold for thermometers used to measure temperatures of the order of 700 or more degrees. The glass of which thermometers are made has a tendency to grow when exposed to high temperatures. To offset this, thermometers are generally aged in the factory, but despite that, and even though properly done, thermometers for high-temperature work cannot be re-

lied upon. When used in such service they should be checked at least once a month, and a careful record made of the changes in their calibration. Where commercial thermometers are installed for indicating superheated steam temperatures or high feed-water temperatures, provision should be made for checking their indications by providing a test thermometer well or thermocouple equipment.

Maintenance of flow meters is perhaps the most difficult of any class of instrument. Their operation is not always well understood, and the average user approaches any maintenance work with a great deal of hesitancy. If instructions furnished by the manufacturer regarding installation and operation are carefully followed, maintenance of this type of instrument should not be more difficult than other instruments usually found in power plants.

The most important thing to be watched is the piping connections from the point where orifice connections are tapped into the flow line to the shut-off valves at the flow meter body. This piping should be kept absolutely free from leaks. All flow meters are based on the principle that there is a difference in pressure between the leading and trailing orifice or nozzle connection, and if by any chance there develops a slight leak in either of these lines the meter cannot help but be in error. Use of copper tubing has done much to eliminate probability of leaks.

Maintenance of flow meters consists, usually, of cleaning the pen and recording mechanism, stopping leaks, and occasionally blowing down the connecting line from the orifice to the manometer body. The length of time between successive blowing down of these lines depends upon the amount of sediment which may enter from the line of flow. Where the steam is exceptionally clean, and the purity of the water approaches that of distilled water, it need not be done oftener than once in several months. In smaller plants, where the steam and water may contain a great deal of sediment, it will be necessary to blow down the connecting lines at least once every month.

At least once a year a water column test should be run on all flow meters to determine whether the meter has retained the calibration set by the factory. The purpose of this is to determine whether the pressure differential imposed upon the meter by the orifice is being correctly interpreted and transmitted to the recording and integrating instrument.

In making a water column test on any meter body, it is necessary to place a differential pressure on the meter equal to the maximum for which it is designed. This pressure is usually obtained by placing in parallel with the high-pressure side of the meter body a water column equivalent to the differential imposed by the orifice connection. This water column must be constructed so that its height can be varied. The diameter of the glass tube should be large enough so that the meniscus is flat and so that all of the air can be easily expelled from the tube.

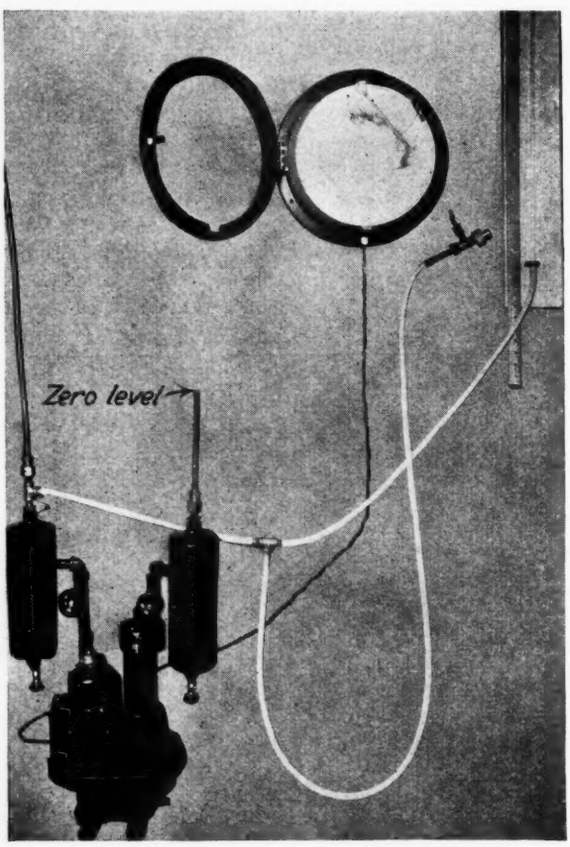
One of the most important parts of the water column test is the zero level, since all distances are measured from this point. A nipple ground to a sharp edge, and inserted in the low-pressure connection to the meter, is a convenient method of obtaining a good zero level.

In the boiler room CO_2 machines, boiler meters and draft gages all require attention. Maintenance of CO_2 machines consists mainly of cleaning filters and gas-sampling piping, and renewing used-up chemicals. Orsat checks should be made at least once a week, although in many plants daily checks are made of these machines. Draft gages should be checked regularly for zero setting and the connecting pipe line blown out with compressed air to prevent soot from clogging the draft tip and causing the instrument to be in error. Where a large amount of ash is carried up through the boiler it may be advisable to blow out the draft lines at least once a month.

A simplified method of setting the air-flow steam-flow mechanism of boiler meters was given by W. G. Lauffer in an article in the July 23, 1929, number of *Power*. The method described makes use of deadweights, and but one Orsat analysis is required. About every two weeks the boiler meter should be checked by Orsat analysis to correct for the dirt and slag accumulations in the boiler passes. If the Orsat check shows a departure from the standard greater than 2 per cent total air the meter setting needs to be changed.

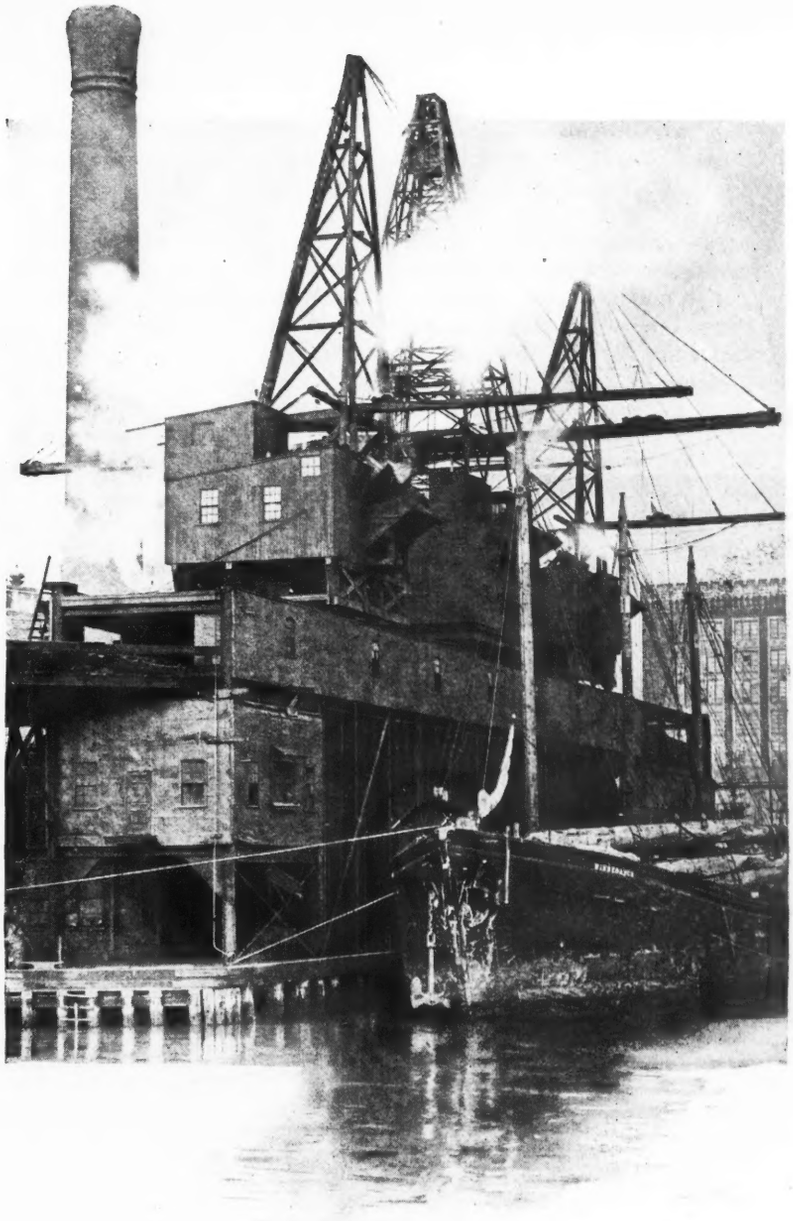
This method furnishes a check on the condition of the baffling. If the change indicated by the Orsat check is not as great as it should be, considering the time the boiler has been in service, it is possible that the baffling is in bad condition.

That instrument indication can be interpreted to show the need of maintenance on other equipment is too little realized and neglected. For example, data from the instruments generally provided on the turbine and condenser can be used to determine when the condenser tubes should be cleaned, whether the turbine blading needs attention, and the frequency of cleaning oil coolers.



Flow meter set up for water column check

Maintaining Service in COAL and ASH HANDLING



With high-sulphur coal, maintenance costs on various types of coal handling systems range from 4 to 6 cents per ton. Coal-handling maintenance approximates 6 per cent of total plant maintenance

▼

FACTORS influencing the selection of coal-handling equipment are location and type of plant, cost of labor and fuel, size of the coal used, tonnage involved, and provisions for plant expansion.

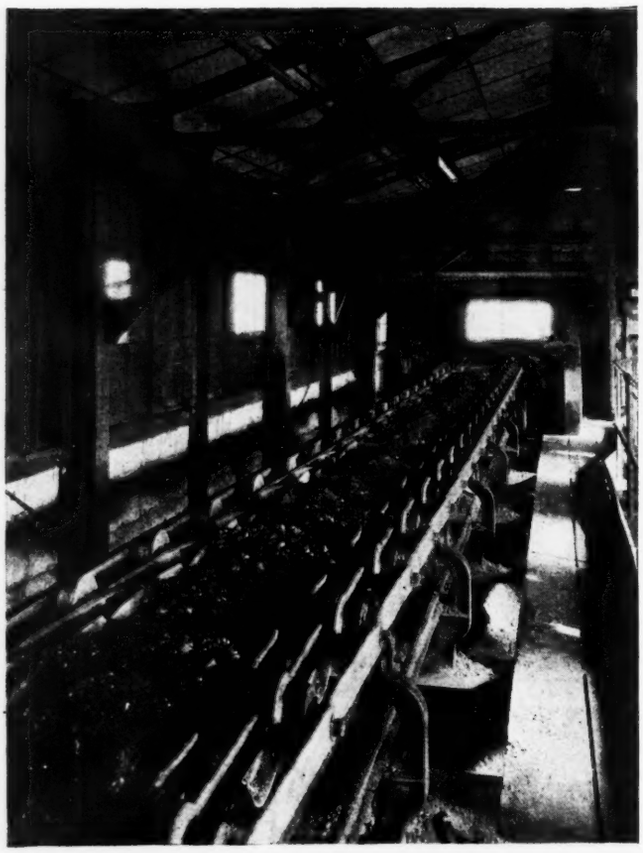
Excepting the smaller plants, where industrial cars or trucks or simple monorail telpher systems may prove adequate, the majority of plants use continuous conveyors, which may be any one or a combination of the following types: bucket elevator, spiral screw; apron, scraper or flight conveyors; pivoted-bucket carrier; belt conveyor; and combination skip hoist and tram car.

Sometimes it may be considered desirable to select certain of the foregoing types for distribution, and, for elevation of the fuel, use any one of the various cranes available, a continuous bucket elevator, a grab bucket, or skip hoist. Storage and reclaiming of coal calls for a variety of cranes, drag scrapers, and, in certain of the larger plants, equipment of special design. In practically all systems of sizable capacity there will appear a number of individual items for specific service, such as a track hopper or car unloader, any one of several types of feeders, a coal crusher or breaker, a magnetic separator if mine-run is the fuel, transfer hoppers, bunkers, coal valves, delivery spouts, and some form of weigh larry. It is with the operation and maintenance of such equipment that this article deals.

In the larger stations it has been found advantageous to keep accurate records of operating and maintenance costs for coal-handling equipment, to establish a definite system of periodic inspection and to centralize the responsibility for maintenance. From the records made available it is possible to reason from cause to effect, and vice versa, so that the major causes of trouble may be eliminated. Looking forward to the detection of wear or deterioration and the correction of the trouble before it assumes serious proportions is the key to low maintenance and good service.

Unfortunately, this practice has not been generally adopted. Throughout the field as a whole there are probably fewer data available on operating and maintenance costs of the coal-handling system than in any other department of the plant.

Barring accidents and assuming reasonable inspection of an adequate system, total maintenance varies with the amount of similar coal handled in a given time and with the length of travel, but when this charge is reduced to a per-ton basis for material and labor, and properly averaged over a period of several years, it is surprising how nearly the various figures for different systems or combinations coincide. The various advantages and disadvantages seem to equalize. Shorter travel may be offset by greater weight and a multiplicity of working parts. The upkeep of a simpler system, with lower maintenance cost per 100 ft. of travel, may be raised to the common figure by the necessity for much longer travel, expensive supporting structures, and perhaps inclosing galleries. In other systems the complication of automatic loading



A horizontal run of a bucket-type conveyor in general use

and automatic operation adds to a low maintenance expense on the primary equipment.

Table I gives an indication of the maintenance cost per ton of coal handled in large systems properly designed and maintained. The figures are from three typical central stations of the Middle West, stoker plants using home coal of high sulphur content and in each case with a separate system for ash disposal. Station A is equipped with belt conveyors and coal breakers. The latest type of anti-friction idlers lubricated with force grease guns is used, but the coal is transported several times as far as in the other stations. Station B is equipped with pivoted-bucket conveyors throughout and uses ring mills. In Station C pivoted buckets are used for elevation and belt conveyors for distribution. Breakers prepare the coal.

The figures in each case are an average for three years. The average unit maintenance for the three stations is 3.85c. per ton of coal handled, and reference to the data of other years indicates that a fair maintenance charge, including material and labor, for these large systems is slightly less than 4c. per ton handled. Crusher maintenance is of interest in that it shows the stability of the large breaker. The figures are inclusive because they take in not only the breakers themselves and the casings, but also the motors that drive them, the hoppers into which they discharge, and the auxiliary crushers that handle the rejected matter from the breakers.

The ratio that the maintenance of the coal-handling system bears to the total maintenance of the station approximates 6 per cent.

Similar data from industrial plants under one management, Table II, indicate that the maintenance charge per ton of coal handled may exceed 5c. Here the figures are derived from the data of a single representative year, so that rebuilding costs do not enter unless part of the work happened to come in the specific year. With one exception the equipment is of the pivoted-bucket type. The exception consists of pivoted-bucket and belt conveyors. In two of the plants both coal and ashes are handled in the same equipment. The actual average in the five plants is 4.12c. per ton, covering material and labor. The low figure in plant E may be attributed, in part at least, to the newness of the installation. That the general average in these industrial plants is 50 per cent higher than in the larger stations, may be explained by the much lower tonnage. The foregoing figures are higher than the entire cost per ton usually attributed to coal handling, but they apply to the entire system and represent actual expenditures in representative plants.

Assuming improved design and the use of material in the construction best suited for the service, the outstanding factor influencing maintenance is the personal element. An operator who is systematic, keeps the equipment tight and in good order, inspects and lubricates regularly, flushes dust off the conveyor at the end of the run, and keeps the runways free from accumulated drippings, will have less maintenance than the careless attendant.

Where power is a factor, anti-friction bearings are coming into general use, particularly because the first cost is not so prohibitive as formerly. They require less attendance, but they must be designed to exclude dust and dirt or they will give more trouble than plain bearings. Concerning belt conveyors, it has been stated that the saving in the labor of greasing and in the cost of the grease ranges from $2 to $2.50 per idler per year. Where it is not advisable to employ these refined bearings, bronze or hardened-steel bushings usually are easier to renew than babbitt, and less expensive than an entire cast-iron roller or bearing.

High-grade speed reducers applied to all types of conveying machinery, or silent-chain drives in oil casings, usually require less attendance and maintenance than open gearing. Owing to higher first cost they may not always be justified unless several units are used, but other factors, such as simplicity, compactness, safety, etc., contribute to their desirability.

Hoppers and Bunkers

All steel plate work, as in hoppers, chutes and bunkers, will last longer if cleaned periodically, freed of rust, and protected by a coat of heavy acid-resisting paint or rust-proof enamel. To preserve the paint on the areas coming in contact with the coal, additional protection is necessary.

For track hoppers heavy gage steel plate or copper

TABLE I—MAINTENANCE COSTS IN LARGE CENTRAL STATION COAL HANDLING SYSTEMS
(Three-year averages)

Station	Conveyor	Crusher	Conv. Maint., cents per ton	Crusher Maint., cents per ton	Total Maint., per ton	Coal Handling to Total Maint., Per Cent
A	Breaker	Breaker	$3.37	$0.30	$3.67	$5.7
B	Piv. bucket	Ring mill	2.71	0.99	3.70	5.2
C	Piv. bucket and belt	Breaker	3.97	0.20	4.17	5.8
Average			3.35	0.5	3.85	5.6

TABLE II—MAINTENANCE OF COAL-HANDLING EQUIPMENT IN INDUSTRIAL PLANTS

Station	Location	Conveyors	Crushers	Service	Age of Equip., Years	Coal per Year, Tons	Maint. per ton cents	Years Average
A	Chicago	Piv. bucket	Ring type	Coal	10	210,000	4.0	4
B	Sioux City	Piv. bucket	Two-roll	Coal and ash	16	36,163	6.0	1
C	St. Louis	Piv. bucket	Ring type	Coal and ash	13	50,466	5.1	1
D	St. Paul	Piv. bucket	Single-roll	Coal	11	71,000	2.3	4
E	Chicago	Piv. bucket and belt	Ring type	Coal	3	103,000	3.2	3
Average							4.12	

bearing steel may be used to withstand corrosion. Other protection is the use of tile or brick linings laid up in cement mortar over a heavy asphaltum paint. Such practice is economical when handling abrasive material like coke and ashes or high-sulphur coal. Dense cement linings applied with a gun over wire mesh is another alternative where the impact of the coal will not crack the cement.

When using high-sulphur coal, and particularly when wetting down this fuel for stoker use, records show that unlined steel bunkers last from four to eight years. They will withstand the service longer, say up to 15 years, if the new steel is scraped and cleaned, covered with heavy acid-proof paint, and a 2½-in. coating of concrete applied. It is important to empty the bunker periodically and inspect the concrete, for if cracks develop from impact of the coal or from the heat of spontaneous combustion, conditions will be worse than if no lining had been used.

Under the conditions outlined coal valves and downcomers from the bunkers have been known to last less than a year. Service for three years may be had if the spouts are painted and the paint protected by 1½ in. of cement applied with a gun. These lined spouts are heavy, but the same objection applies to spouts of cast iron. Copper-bearing steel has been used, and, upon occasion, wooden linings over painted metal.

In transfer hoppers of large size, where the drop of the coal may be 15 to 20 ft., concrete lining will crack on the plates subject to impact. An alternative has been the use of a lining of cast-iron plates 1 ft. square and 1 in. thick, each plate secured by a single bolt. In severe locations these plates last two years, and much longer in less-exposed places. They can readily be replaced, so that, in the case under discussion, a hopper of ⅜-in. plate will last ten to fifteen years, compared to two and one-half years for the unprotected hopper.

Silos should have the coal withdrawn periodically so that the walls may be checked for cracks that might admit moisture to the reinforcing steel.

Railroad crane and clam shell bucket for coal handling

From the track hopper coal is generally removed to the crusher or conveyor by one of three types of feeders. The reciprocating plate feeder is effective where the fuel need not be carried more than 10 ft. It is simple and has little to maintain except the bearings of the drive and the gears. The flanged bottom plate is easily and cheaply renewed. Reciprocating cranks and eccentrics should be of ample proportions, and spares should be kept on hand. Supporting rollers should be provided with bronze bushings. An apron or pan conveyor may be used for conveying some distance from the hopper. First cost is more than for the reciprocating type, but as it operates at slow speed and can be strongly made, maintenance is low. Because it transports the coal, little power is required. As the chain rollers are the first to wear, they should have chilled treads, single-flanged, and be fitted with case hardened bushings. The chain links should be thick enough to give low unit bearing pressures. Pins of alloy steel, heat-treated, are preferable.

Heavy aprons should have cross rods from one strand of chain to the other to prevent the chains from leaning toward the center under load. These heavier aprons also should have T-rail tracks, on the upper run at least, because angles wear out more quickly and are difficult to replace. Although higher in first cost, good speed reducers may well replace the long gear trains more commonly used to obtain low conveying speeds. They require less attendance, and maintenance costs are lower. Inclosed self-oiling rollers require less care than plain rollers. Pins fitted for forced oiling are becoming popular owing to their ease of lubrication. Delivery of coal from the track hopper may be effected by skip bucket loaders of either the "damming" or "full-bucket control" type. Bucket loaders require less attention if made of heavy-gage copper-bearing steel to withstand both corrosion and abrasion. To facilitate maintenance hinge-shaft bearings should be bushed.

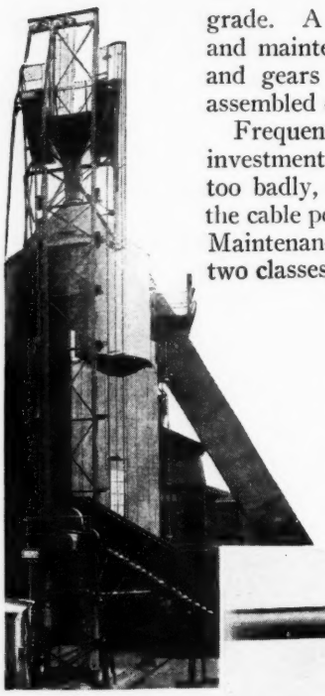
One of the simplest coal-elevating units is the centrifugal discharge elevator. As the buckets pass over the head wheel the contents are discharged by centrifugal force into a chute. The buckets usually are attached to a single chain or belt and are self-filling as they pass through the boot. Malleable buckets with thick lips are preferable to withstand corrosion and abrasion. Buckets should not exceed 14 in. in length, because the twisting action in digging through the boot is a severe strain on the chain. Care should be taken to keep long sticks, large pieces of iron or other hard material out of the boot, as they may wedge and tear off a bucket or break the chain. Chains and belts should be inspected fre-

quently for wear or deformed links.

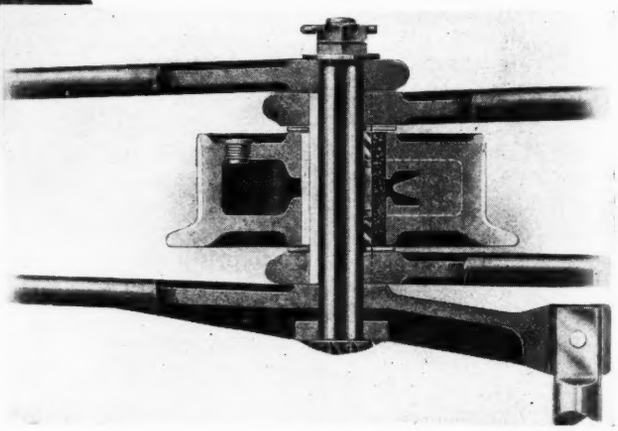
An improved elevator for somewhat larger capacity is the continuous bucket-type. The double-strand chains and the sprockets should be aligned properly and inspected frequently. Inspection with plumb line for alignment of tracks and travel should be made to prevent binding. The coal should be fed by a loading leg directly into the buckets as they start their ascent. Copper-bearing steel casings well stiffened with angles reduce maintenance.

What has been said of alignment, chain guides, and casings applies to the gravity-discharge-elevator conveyor. Heavy copper-bearing plates for horizontal trough runs are worth the extra first cost. Easily operated rack-and-pinion gates are better than hand slides. The larger sizes should have chains with single-flanged rollers running on T rails to prevent the buckets from rubbing on the edges of the trough. The comments previously made on apron conveyor chain also apply here.

For the past thirty years the pivoted-bucket carrier has been used more than any other type for the handling of both coal and ash, owing to the simplicity of loading and of delivery, the limited space requirements, and the small amount of power needed. Slow operating speeds and the use of malleable buckets and chain links to withstand corrosion have contributed to low maintenance.



Skip hoist and coal storage for outside installation



Conveyor links and wheel designed to reduce wear and maintenance

Under apron and gravity-discharge conveyors, the remarks made on chains will apply generally. To guard well against corrosion, frequently buckets are of seamless malleable iron. Preferably the chain links should be of the same material and have broad bearing areas, so that ample surface remains even after corrosion has made some headway. Loading runs should have guard rails and loading guards. Safety switches preventing the operation of the carrier with the buckets in an unnatural position must be kept in good condition. It is important to clean up regularly under the loading run to prevent accumulation of coal drippings or other material from wedging the buckets or throwing the chain rollers off the track.

In some plants it is the practice to rebuild these conveyors every seven to nine years. It may be necessary to renew chain links, bucket trunnions and lips, and the bucket axles. Frequently it is feasible to ream out the links and the rollers to $\frac{1}{4}$ in. larger diameter and put in a new axle, thus saving the rollers and chain links. The buckets being of malleable iron, it is seldom necessary to replace them in entirety. The lips may be built up by welding on new material, and the trunnion and dumping cam renewed. The rails, particularly at the corners, may need replacing.

To reduce wear and attendance, the rollers should have chilled treads and be equipped with roller or bronze-bushed bearings. To minimize skilled attention it is advisable to use electrical control equipment of the highest grade. A hoisting machine will require less attention and maintenance if equipped with anti-friction bearings and gears in oil housings, and if the entire hoist is assembled on a unit base.

Frequent lubrication and cable inspection is a good investment. The cable should be renewed before it wears too badly, as loose strands may foul the equipment, or the cable possibly may break and allow the buckets to fall. Maintenance on belt conveyors may be divided into two classes, that on the belting and that on the machinery parts. In either class the cost of maintenance depends largely upon three factors, general conveyor design, construction of unit equipment parts, and operating attention. The last named is of utmost importance in prolonging belt life. Inspection that will catch the trouble before it happens is the secret of successful operation. Barring accidents, belt renewals in power plant service range from three to six years, compared to ten to fifteen years for machinery parts.

Belts should not be run tighter than is necessary to prevent slipping, as an over-tight belt wears out rapidly. They must be kept properly aligned by adjusting the idlers in the direction of belt travel. Idlers so adjusted in an initial installation eliminate guide idlers, which tend to chew the edge of the belt. Narrow gaps between rollers prevent creasing of belts maintained soft so that they may trough readily. Use of decking between troughing and return idlers is always advisable. Otherwise a piece of material dropping from the upper strand of the belt may be carried along by the lower strand to the end pulley. In being squeezed between pulley and belt a puncture in the rubber covering may result, allowing moisture to penetrate the duct and rot it. A piece of material wedged between an idler pulley and the decking may prevent the pulley from revolving and cause abrasion of the belt.

In the operation of a belt one of the cardinal points is to keep the conveyor decking clean. An accumulation of coal around the idlers and conveyor pulleys is not conducive to low maintenance. Use of a belt wide enough for the service, side skirts and properly designed loading chutes help to eliminate this trouble.

About once a week it is well to go over the belt carefully and look for cuts or abrasions in the protective rubber coating. Breaks of any character permit moisture to get into the fabric, rot it, and so weaken the

belt that it may have to be discarded. These spots should be cleaned out thoroughly, first with gasoline and then with alcohol, to remove any surplus moisture, and filled with rubber cement or repeatedly covered with non-drying paint. Belt splices are the weak spots and so require special attention.

A solenoid or automatic back-stop brake should be used on the drive of an inclined belt to prevent the belt from running backward if power is interrupted.

If a belt is out of alignment the edges will wear off against frames or other obstructions, and the bottom of the belt is liable to injury by riding on the edges of the troughing idlers.

Belts never should be trained by increasing the tension, as this only strains the driving mechanism, increases the power requirements, puts an unnecessary stress on the belts, weakens the splice, takes out the troughing of the belt, and eliminates the effective training action of the center idler roll.

Tripper pulleys should be inspected regularly to see that belts do not scrape against the frame. Skirt boards must not come in contact with the belt. They should be cut away or so set that the space between board and belt increases with the direction of the travel, so that pieces of material may work free rather than become wedged against the belt to gouge the covering or perhaps push the belt to one side.

If lubricated properly, anti-friction idlers give little trouble. Noisy idlers are an indication of excessive clearance. Defective units should be replaced.

Screw conveyors are so comparatively simple that, outside of the wear of the flights and possible wedging by chips or tramp iron, there is little to say from the operating or maintenance standpoint.

Flight conveyors, consisting of either one or two strands of chain-carrying flights that push the material along a trough and discharge it through gate-controlled apertures in the bottom of the conduit, require considerable power and must be built to withstand wear. The chains and sprockets must be accurately aligned to prevent binding, and be inspected frequently. Power requirements and the maintenance of the tracks and trough are reduced if the flights are supported at the ends by single-flanged rollers. Sprockets at turns relieve the rollers of track loads, and they should be used rather than short curves.

Since the development of combustion equipment requiring smaller sizes of coal, $\frac{1}{4}$ to $\frac{3}{4}$ in., the problem of crushing has presented new maintenance factors. If high-speed hammer mills of various types are used, cast-steel construction and oversize anti-friction bearings are indicated. These machines also present a problem of dust collection, owing to the churn-like fan action of the rotor within the crusher casing. Here again it is advisable to reduce crusher speed if low maintenance is to be obtained without increasing unduly the fixed investment charges of the plant. Hammer replacement needs frequent attention.

The power hoe and skip hoist used at Capitol power plant, Washington, D. C.

Operating upon much the same principle, the high-speed, ring-type mill has proved economical and efficient for capacities ranging from 50 to 150 tons per hour. Maintenance consists chiefly in the renewal of rings and grate bars to insure proper sizing.

In large plants requiring capacities in excess of 150 tons per hour the coal breaker has virtually become standard. Over the life of the equipment the high initial cost is overcome by many economies. Being simple and built substantially, it is a most dependable machine. There is little maintenance outside of tightening or renewing bolts affected by the jar of the falling coal, and the infrequent renewal of the perforated screen plates to maintain proper sizing. When the coal is running wet, the screen openings may clog. One-inch-link chains hung in the breaker so that they may trounce around on the screens will keep the openings clear.

Ash Removal

Ashes may be in the form of clinker; they may be fine and powdered, red hot or cold, dry or dripping wet, perhaps giving off gases or steam, and usually containing at intervals furnace refuse such as broken down refractories. Almost always there is a certain amount of quenching water present. Because of the abrasive action of the ash, whether wet or dry, and the corrosive effects when the coal is high in sulphur, the trend is toward separation of coal- and ash-handling systems. Industrial cars, semi-automatic skip hoists or the pivoted-bucket carrier are common means of ash conveyance. Ultimate delivery is usually to an overhead bin discharging to railroad cars or trucks.

Owing to their compactness and their limited space requirements, steam-jet and pneumatic systems using a pipe line as the conveyor have become popular. In these systems maintenance centers in the pipe line, in the renewal of wear plates, and possibly in the storage tank if it is exposed to freezing weather. In certain of the pneumatic systems, operating on suction pressure, the ashes are delivered dry, so that the freezing problem is eliminated, and, by means of a washer, also the dust nuisance.

In large plants, where water is plentiful, ash sluicing has become common. Here replacement of ash pump impellers is the largest item under maintenance expense.

Coal Preparation and Burning Systems

Stokers receive better attention in operation, with consequent reduction in maintenance, if the room is kept clean and well lighted

An important factor in obtaining high plant efficiency is the condition of the fuel-burning systems, which depends mainly upon the kind of maintenance the parts receive; for that reason scheduled overhaul is a vital necessity

IT HAS been demonstrated in a number of instances that with a modern stoker unit operated at high ratings under skilled operators maintenance need not exceed 1½ to 2c. per ton of coal burned. With what might be termed fair operation, which is the more general condition, these charges will run from 3 to 5c. With careless operation they may reach 15 or 20c. a ton. Of the total maintenance charges on any stoker unit, between 70 and 80 per cent is for renewal of parts inside the furnace, where they are not readily seen or inspected; hence the more need for reliable operation.

Assuming that it is desired to maintain a stoker to operate at its original efficiency, the following factors will be found to have a direct bearing on the cost of maintenance: Original design, method of operation, and cost of replacement parts. The first is essentially one of selecting the proper design of stoker for the coals commercially available and installing a unit of sufficient size to meet the maximum demand for steam without forcing it to burn excessive amounts of coal per square foot of grate area.

The second factor is probably the more important. It involves keeping the proper form of fuel bed with a uniform flow of air through it to prevent burning or warping of the grate sections. This applies to both underfeed and chain-grate types. Proper banking is also important.

The third factor, namely, the cost of replacement parts, usually receives most consideration by the owner, although it may represent but 25 per cent of the total maintenance cost. Often, in an endeavor to economize, the owner has tuyères and other parts cast at a local foundry. This practice may result in increased rather than decreased maintenance cost, and usually increases the labor charges because of the necessity of chipping or otherwise fitting the piece to the stoker.

It should be appreciated that accurately made parts in a stoker are just as important as in any other unit, and that they can not always be obtained locally. Breakdown and excessive maintenance have frequently been blamed on the manufacturer, whereas later investigations have traced the cause to improperly fitted replacement parts. Furthermore, improvements are constantly being made by manufacturers in an endeavor to produce better operating units and at the same time reduce the cost of upkeep. Thus, the owner by keeping in touch with the manufacturer may receive the benefit of these improvements as they are made available.

It is much better to shut down a stoker at a definite

time for inspection than to be forced to shut it down when it is badly needed. During a shutdown the stoker should be gone over thoroughly, and any grates showing indication of possible failure during the next operating period should be replaced. In this way a forced shutdown may be avoided, with consequent saving not only in material and labor but also in the prevention of undue expenditure throughout the plant caused by having to take a unit off the line when it is needed.

One of the best ways of keeping a stoker in proper working condition is to establish a detailed inspection at regular intervals. A record of these inspections makes a good basis for determining the number and kind of renewal parts which should be kept on hand. Although there are too many factors involved to make any definite ruling as to how long a stoker should be operated between inspection or overhaul periods, experience would seem to indicate that an inspection every four months and a complete overhaul once a year is essential in order to maintain reliable and continuous service. The procedure of overhauling a stoker will, of course, vary with the type of unit. However, the same general principles apply. The larger part of the work in an underfeed type of unit will be renewal of tuyères and overfeed sections. All tuyères that have been burned sufficiently to seriously affect or change the ratio of heat-absorbing to heat-liberating surface should be renewed. When tuyères are badly burned not only is the fuel burning capacity of the stoker greatly reduced but the air passages through them will have become so restricted that more burning is inevitable.

In purchasing new tuyères, or, in fact, any renewal part previous to the general overhaul, advantage should be taken of any improvements in design that have been made by the stoker manufacturer. This is all the more important if the unit has been in service a number of years. Recent tuyère designs show improved streamline passages that give better air distribution and cooling than was afforded by the older types. There is also less tendency for the ash to fuse readily to the tuyère, and extended cooling surface gives greater protection against burning. Some manufacturers have recently made available tuyères with renewable nose pieces, ram and box caps with renewable extension pieces, and other parts subject to frequent renewal have been changed in design to facilitate replacement. Advantage should be taken of these improvements, for invariably they are applicable to the older units and when installed materially reduce the annual maintenance expense through saving in material and labor.

Although the capacity of an underfeed stoker is affected most by improper maintenance of the grate section, it is equally important that all other parts receive a thorough inspection and necessary replacement during the regular overhaul.

Dump plates should be tried for freedom of operation, and any clinker that has formed at either end removed to prevent fouling of plates when the stoker again goes into operation. If a clinker grinder is used the bearing holding bolts should be gone over and tightened. The ratchet-and-pawl-mechanism also needs its share of attention.

Although little fuel burning actually takes place in the retort directly inside the front wall, burning of the ram box caps does occur from time to time. Where this has been sufficient to leave a portion of the wall unprotected, renewal of the extension pieces or complete cap should be made as necessitated by the stoker design. Owing to the usual angularity of the connecting rod operating the feeding ram and to the resistance of the coal, the ram

STOKER MAINTENANCE REPORT

Plant _____ Year _____

Stoker No.— _____ Name of Workman— _____

Date of Last Inspection _____ Inspection—A _____

Date of Previous Overhaul _____ Inspection—B _____

Hours Operation Since Overhaul _____ Overhaul _____

NAME OF PART	REPORT OF INSPECTION & OVERHAUL			REMARKS	REPAIRS		Total
	Inspection A Date	Inspection B Date	Overhaul Date		Material	Labor	
Tuyéres and Overfeed Section							
Dump Plates							
Ram Boxes & Caps							
Gear Box							
Crankshaft, Connecting Rods and Bearings							
Secondary Rams							
Air Dampers							
Sealing Strips							
Miscellaneous							
Total Maintenance Charges							

Above—A record of inspection makes a good basis for determining the number and kind of spare parts to be kept on hand

and ram box are subjected to considerable wear. It is therefore important that the ram box sleeve be renewed or the wearing plates, with which some stokers are fitted, be adjusted to normal setting.

If a stoker has been operated more or less continuously since the last overhaul, the gear box should be drained and flushed out with kerosene. If the condition of shafts and thrust bearings cannot be determined by removing the cover the box ought to be completely dismantled and all bearings inspected. Particular attention must be given to the thrust bearings to insure correct alignment of worm and worm gears.

Operating experience has shown that the use of water-cooled furnace walls and preheated air have considerable influence on stoker maintenance. Water cooling of the rear wall is particularly advantageous, owing to the cooling effect on the lower end of the stoker. A limited amount of preheat (up to 350 deg.) in the air tends to reduce stoker maintenance through the ability to maintain better fuel bed conditions in the furnace. With some classes of coal a thinner fire can be carried, and there is less tendency to clinkering.

Unlike the underfeed, the surface of a chain-grate stoker is visible at all times. Thus it is not so necessary to take the stoker out of service for periodic inspection. When the stoker is down for overhauling, in addition to the replacement of burned grate links, the side seals should be inspected and adjusted to give proper sealing against the webs of the grates, to guard against infiltration of air along the sides, and to prevent sifting of fine coal.

Alignment of front and rear sprocket wheel should be checked and the chain given the proper tension. The feed gate must be tried for freedom of movement and any broken refractory lining blocks renewed.

When putting a stoker back into service after a general overhaul it is advisable to run the unit for a short time at slow speed to see that everything is in order. Operating for a few minutes at full speed with maximum stroke on secondary rams or other reciprocating parts before feeding coal will often prevent an interruption after the stoker is again put into service.

A typical inspection and maintenance sheet is here shown. This form provides a convenient method of recording the condition of a stoker unit at each inspection, the number of replacement parts used, and the cost of material and labor for a one-year period. This sheet can be readily modified to suit any particular type of stoker or installation.

Maintenance of coal-pulverizing equipment differs from that of stokers in that it is influenced more by the kind of coal than by methods of operation. The abrasive characteristics, of the coal, which are influenced by impurities such as pyrites, slate, etc., that it contains, have a direct bearing on the life of the pulverizing elements. Based on a study of a number of plants using both the storage and unit systems handling Eastern bituminous coal, the cost for maintenance (labor and material) varies from 4 to 7 per cent per ton of coal milled. With lignite this charge is around 2 to 4c. per ton.

With a fixed kind of coal there is little that can be done to decrease maintenance. It is a fact, however, that if certain types of machines are overloaded or underloaded the maintenance will be increased. In other words, they must be fed with the proper amount of coal in relation to the amount being taken out if excessive maintenance

COAL UNIT NO. 1

On weeks 1,4,7,11,15,19,25,27,31,35,39,43

47,51 inspect as follows:

SCALES - General inspection, belts, etc.

MILL - Internal, oil gages, lubrication, etc.

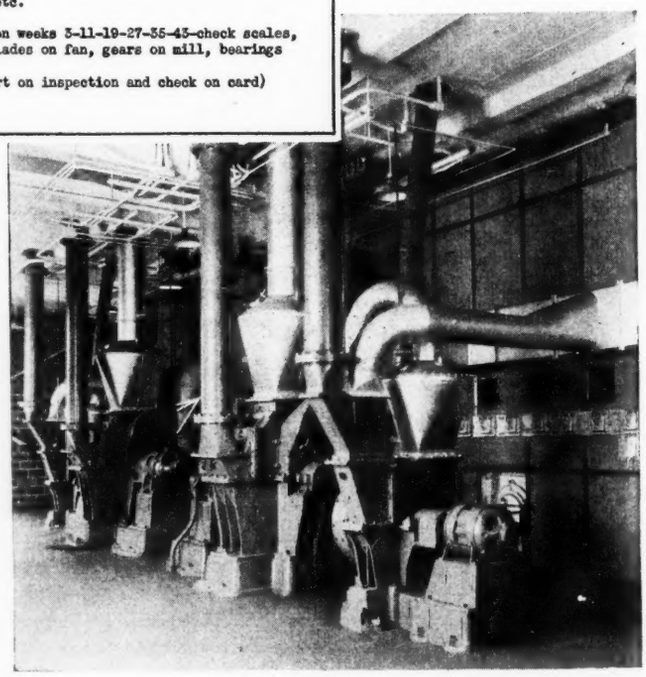
AIR GATES - General

FANS - Bearings etc.

Also on weeks 3-11-19-27-35-43-check scales, inspect blades on fan, gears on mill, bearings

(Report on inspection and check on card)

In one plant the coal unit is inspected every four weeks and certain parts are examined for wear every eight weeks



Neat arrangement of unit-type coal pulverizers in a large public utility

REPORT OF INSPECTION COAL UNIT NO. 1

Week No. 7- Complete inspection. Blades on exhauster worn.
Week No. 9- New blade put in exhauster *A and B
Plate welded on raw coal chute, B
Mill and feeder inspected, O.K. A
Week No.11- New balls and pushers put on mill A and B; fixed mill control, F
Week No.16- Complete inspection, A and C
Complete oiling and greasing B
Week No.17- Welded plate on raw coal chute E
Week No.18- Repacked mill and repaired oil lines, removed oil line to stuffing box A
* Workman

This report shows when inspection was made and condition of coal unit

is to be avoided. With the many coals being used, the life of pulverizing elements varies widely, and no one schedule of inspection or maintenance is applicable to all cases. When an installation is first started inspections should be made frequently and records taken of the wear on the grinding elements, with a certain kind of coal, as a basis for renewal of the parts. Where the mills are supplied with dry coal of fairly uniform abrasiveness, a proper schedule for the replacement of parts can be definitely established. But if wet coal is used and the moisture content varies widely the length of life of parts subject to wear cannot be so readily determined. Records of operating experiences

Station ——— Month of ———

LABOR and MAINTENANCE ACCOUNT

Figures represent cost in cents per ton (2,000 lb.) of coal burned

MAINTENANCE ACCOUNTS				ONE MONTH THIS YR	ONE MONTH LAST YR	12 MONTHS THIS YR	12 MONTHS LAST YR
Coal Burned, Tons (2,000 lb.)							
MAINTENANCE OF STRUCTURES COAL MILL BUILDINGS	317	Labor	L				
	317	Material	M				
	317	Total	L–M				
REPAIRS–MISCELLANEOUS	318	Labor	L				
	318	Material	M				
	318	Total	L–M				
REPAIRS–DOCK	319	Labor	L				
	319	Material	M				
Acc't No.	319	Total	L–M				
322.0 Coal Tower			L				
322.1 Crusher			L				
322.2 Belt Conveyor			L				
322.3 Grab Buckets			L				
322.4 Hoist (Incl. Trolley)			L				
322.5 Bucket Conveyors			L				
REPAIRS–COAL HANDLING MACHINERY	322	Labor	L				
	322	Material	M				
	322	Total	L–M				
323.0 Dryers			L				
323.1 Mills			L				
323.2 Mills & Dryer Exhausters			L				
323.3 Cyclones & Air Washers			L				
323.4 Coal Transport Pumps			L				
323.5 Transport Piping			L				
323.6 Weigh Bin & Weighing App.			L				
323.7 Coal Bunkers (Raw Coal)			L				
323.8 Coal Chutes			L				
REPAIRS–DRYERS, MILLS PULV. COAL TRANS. & WEIGHING SYSTEM	323	Labor	L				
	323	Material	M				
	323	Total	L–M				
Total Maintenance Charges							

Maintenance report shows cost of material and labor in cents per ton of coal burned

TROUBLE REPORT

Date Sept. 19, 1929

TROUBLE #3 Mill.

CAUSE Overhauling.

REPAIR
Dismantling mill.
Overhauled mill shaft bushings and mill feeders.
Renewed bull ring. This bull ring was installed on Aug. 27, 1928 and was renewed on Sept. 19, 1929. The service hours between these dates are 4780 mill hours.
Renewed tips of plows.
Stellited plow tips.
Removed defective bushings from mill roll castings.

TIME
Made up adjustable sleeve for mill.
Prepared mill roll to replace defective roll.
In service 9/19/29.

REMARKS Renewed bull ring. This bull ring was installed on Aug. 27, 1928 and was renewed on Sept. 19, 1929. The service hours between these dates are 4780 mill hours.

Report of work done on mill during a complete overhaul

with different types of mills would seem to indicate that a schedule requiring inspections be made at a definite time and on a certain shift has much to recommend it over one based on a certain number of hours of operation or tons of coal milled. Operating experiences have also shown that if these inspections are made on the day shift they are likely to be more thorough than if made on the night shift in artificial light.

With any type of mill attention to lubrication has an important bearing on the upkeep. Adoption by various manufacturers of oversize anti-friction bearings wherever possible, together with improved methods of sealing the bearings against dirt, and improved methods of lubrication, have been a big factor in reducing maintenance cost. Operating experience has demonstrated that with mills so equipped, when given proper attention, the maintenance charges, other than for grinding parts, can be kept low.

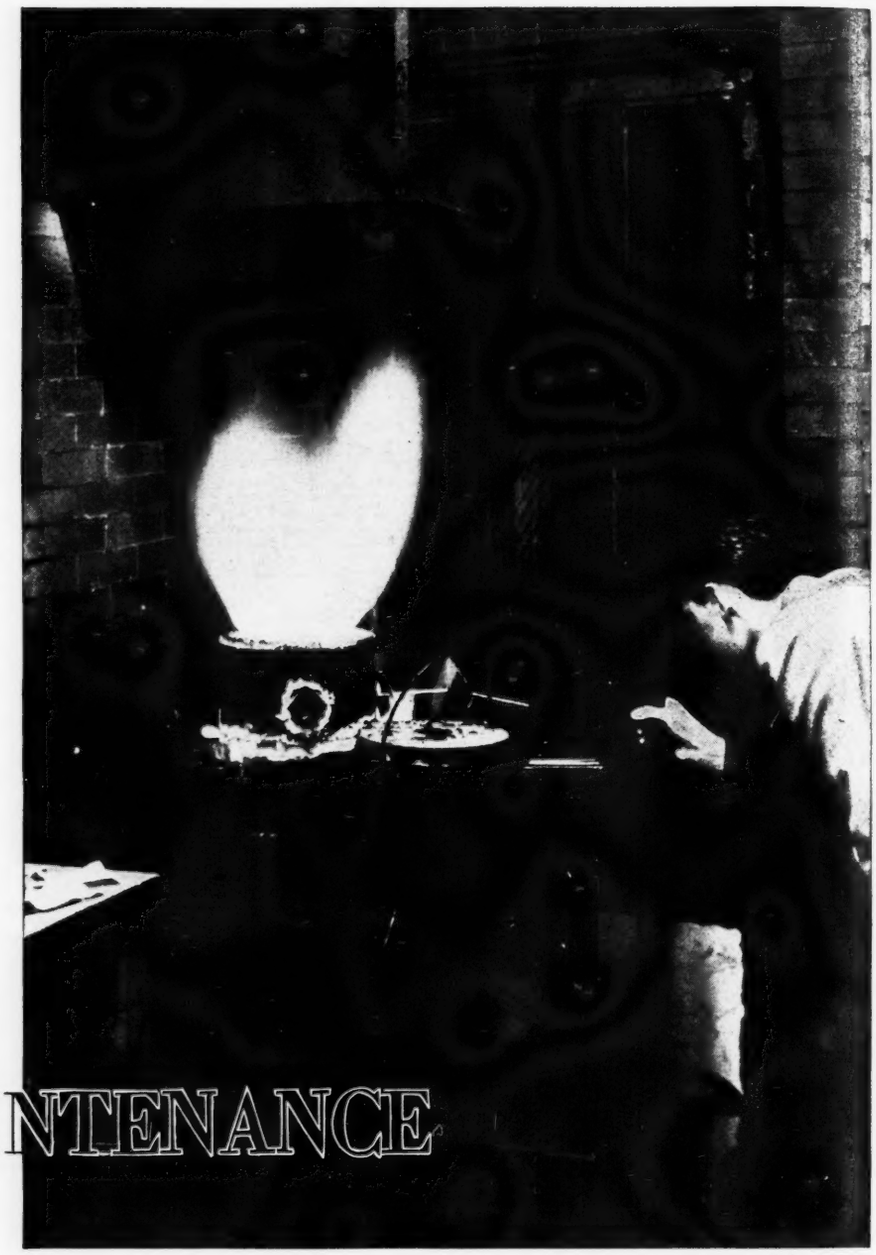
Many of the remarks made previously in this article as to the advantages of periodic inspection of stokers apply equally to pulverizers. With proper care in operation a complete overhaul of a mill, other than to replace grinding parts, should not be necessary more than once a year. At that yearly overhaul the mill should be completely dismantled, so that every part can be thoroughly inspected and the necessary replacements made. Wear on bearing and shafts should be checked, with special attention to the thrust bearings on vertical-type mills. It is now the practice in many plants to build up small bearings, shafts, and other parts by welding.

Another important item in the pulverizer maintenance account is that of blade renewals on the exhauster or fan used to discharge the coal from the mill. Considerable experimenting has been done by manufacturers with different facing materials in an endeavor to increase the life of this particular element. These experiments have shown that it is possible to go only so far with materials, and further advancement must be made in the design of the piece. In one unit type of mill it was found that the wear on fan blades, which were of steel plate, was concentrated in a rather small area. The design was changed to drop-forging, which was thickened at that particular point, and the life was doubled.

Good results are also being obtained with mild steel blades having strips on the face at right angles to the direction of flow. These strips, generally of stellite or steel welding rod, are made approximately $\frac{1}{4}$ in. in height and spaced 1 to $1\frac{1}{2}$ in. apart. Corrosion is also a factor in the life of fan blades, particularly if moist coal high in sulphur is handled, but the use of strips on the blade face has materially lessened that action.

To reduce wear on the exhauster blades to practically nil in one system the fan is placed on the return side of the cyclone collector. In this position only from $\frac{1}{2}$ to 2 per cent of the coal is handled by the fan. It also makes possible the use of a more efficient fan.

Stelliting has also proved effective on plow tips of roller mills; in many cases the application of this method has doubled the life of the plows. Increased life of feeder and transport pump screws has also been obtained by the application of Stellite to the helix.



Laboratory tests give valuable data on the physical and chemical characteristics of furnace refractories but generally must be backed up by open tests in actual full-sized furnaces under regular operating conditions

Ewing Galloway.

FURNACE MAINTENANCE *Under* Modern Practice

THE BUSY ENGINEER confronted with the problem of keeping the plant going at all times may see little opportunity for any economic study in connection with the maintenance of boiler furnaces. It may strike him that the problem is simply one of buying good materials and using good workmanship in their application to the repair of furnace walls whenever they fail or reach the point where failure in the near future is probable.

As a matter of fact, however, economics enters into this problem just as it does into every other problem of plant operation.

It is true, of course, that no knowledge of abstract economics can tell an engineer which brick is best for his condition, what is the best way to lay it up, whether water walls are superior to brick walls, to what degree CO_2 should be sacrificed to furnace life. On the other hand, he can, with his experience and engineering knowledge, obtain practical data to which economic principles can be applied in determining the best method among two or three considered.

The cost of owning and using any given furnace may be divided into several parts. First are the fixed charges on the money actually invested. Then there are the direct expenditures on furnace maintenance.

A third part represents resulting losses in boiler operation. That is, if to protect the refractory the operator reduces the CO_2 and the furnace temperature below the point that would be best considering combustion and boiler efficiency alone, the equivalent waste of fuel may be considered as part of the cost of using this refractory.

In many cases it is necessary, for a true comparison,

to add a fourth cost. Where the use of a given refractory or type of wall construction limits the capacity of the boiler, it thereby reduces the return obtainable from the total investment in the boiler unit, or increases the investment required per unit of maximum boiler capacity. Fixed charges based on this increased investment are really part of the cost of using the given type of furnace.

In addition to these charges, the cost of operating with a given type of furnace must include the total cost of shutdown for repairs. These always involve some loss of heat in cooling off boilers and starting fires. They also, in some cases, involve much heavier losses, due to the inability of the plant during such period to meet the full industrial demand.

No rule, formula, or laboratory test yet discovered is a safe guide to the problem of furnace maintenance. Actual records of operating experience are still indispensable, in spite of the extensive studies that have been made in the search for fundamental scientific principles.

This is particularly true in the selection of firebrick and special refractory shapes. When the attempt was first made to apply scientific principles to the selection of refractories there was a tendency to underestimate the complexity of the problem. Some who had observed what they thought to be the melting of refractories on the inner surfaces of walls imagined that it was simply a problem of melting point. Attempts were made to compare the laboratory melting points of various refractories and thereby determine which refractories would be suitable. These attempts largely failed. It was found that practically any good firebrick has a softening temperature well above that found in furnace walls.

Then it was discovered that the molten substance running down hot furnace walls is not simply melted firebrick, but a material formed by the fusion of firebrick and ash. This material, it was found, has a much lower melting point than the firebrick, the exact point depending on the composition of the ash, as well as that of the brick, and on the amount of excess oxygen (or lack of it) in the atmosphere at the portions of the wall affected.

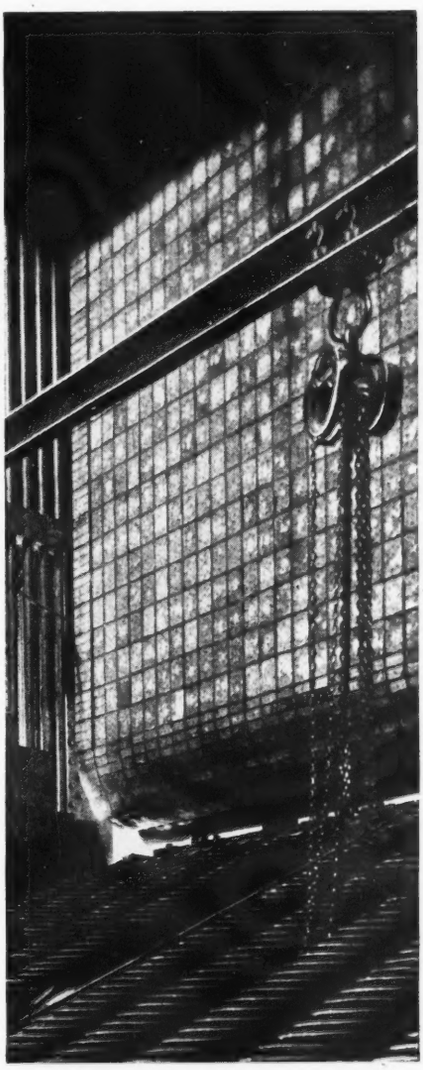
In addition, there is the matter of spalling. The old idea that this was due to expansion and contraction under heat changes was correct so far as it went, but gave an over-simplified picture. It was later found that slag composition has some connection with this problem. It was also found that spalling is associated with the heat gradient, or fall of temperature, through the wall, and the resulting unequal expansion. Many other factors enter in.

Another operating condition not found in the laboratory is the mechanical action of large walls. The behavior of a single brick, or of several bricks, even under actual furnace conditions, is not a sure guide to the action of a complete wall built of such bricks, with its cumulative expansion and contraction and other mechanical actions.

Still another factor in actual operation is the infiltration of air around the blocks. A very slight inward air leak greatly protects the refractories, not only by cooling them, but also by changing the atmosphere from reducing to oxidizing, thereby raising the melting temperature of the slag.

As already indicated, the maintenance of refractory walls involves many factors. These include the kind of brick, its shape and uniformity, kind of fireclay or cement used for joining, thinness of joints, method of laying and bonding, thickness of wall, nature of outside wall, method of firing, shape of furnace in reference to stokers or burners, heat release per cubic foot of furnace volume, and many others. In short, it is one of the most complex problems in the whole field of power engineering.

The accumulation of experience over many years, has, however, given the designer certain principles to work upon. Combining these with ordinary "horse sense," he is continually reducing maintenance cost, although the most carefully prepared designs will now and then prove faulty when new conditions of fuel or firing are encountered.



Corner of stoker-fired setting, showing refractory faced water walls in front and bare tubes on upper sides

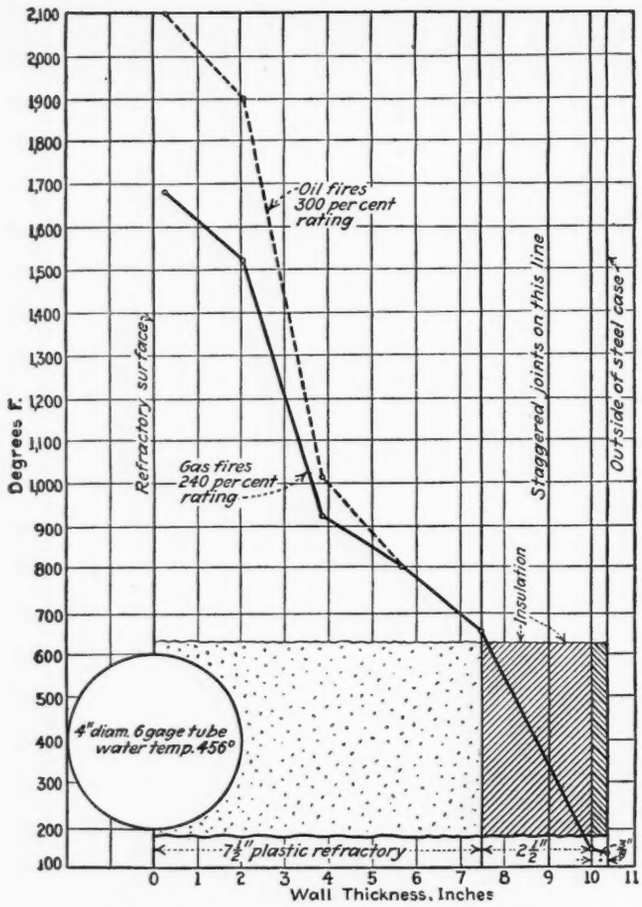
Firebrick is generally laid up with thin "slurry" composed of 60 per cent calcined fireclay and 40 per cent raw clay, both of a composition similar to that of the brick used. It is generally agreed that the joints should be as thin as possible, with virtually a brick-to-brick contact.

By exercising care in manufacture, it is generally possible to produce brick of given dimensions within a tolerance of plus or minus 2 per cent. Uniformity is important, because it permits thin joints and thus greatly increases the furnace life.

In the days of less severe service it was common to back firebrick with common brick. With higher furnaces, operating at higher ratings, this caused trouble, due chiefly to a difference in the coefficients of expansion, resulting often in broken bonds between the two rows. It is now considered better practice to use firebrick all the way through. The outer row may be of a lower grade, but should have a similar coefficient of expansion.

Voids in walls cause breaks in the temperature gradient, and irregular expansion, which may lead to cracks.

The temperature of furnace walls, and hence their life, is affected greatly by the rate at which they receive and give off radiant heat. It is therefore an important principle of furnace design that walls should be placed to "see" as much



Temperature drop through a refractory facing measured midway between tubes of 9-in. spacing

as possible of the lower tube bank, and as little as possible of the fire.

A problem closely associated with maintenance is that of the accumulation of slag and clinker on the lower side walls with underfeed stokers. To prevent this it is common practice to use special blocks, water or air-cooled, along these walls. Ventilated refractory blocks are frequently employed, the incoming air lowering the temperature, and also producing an oxidizing atmosphere which retards slag erosion.

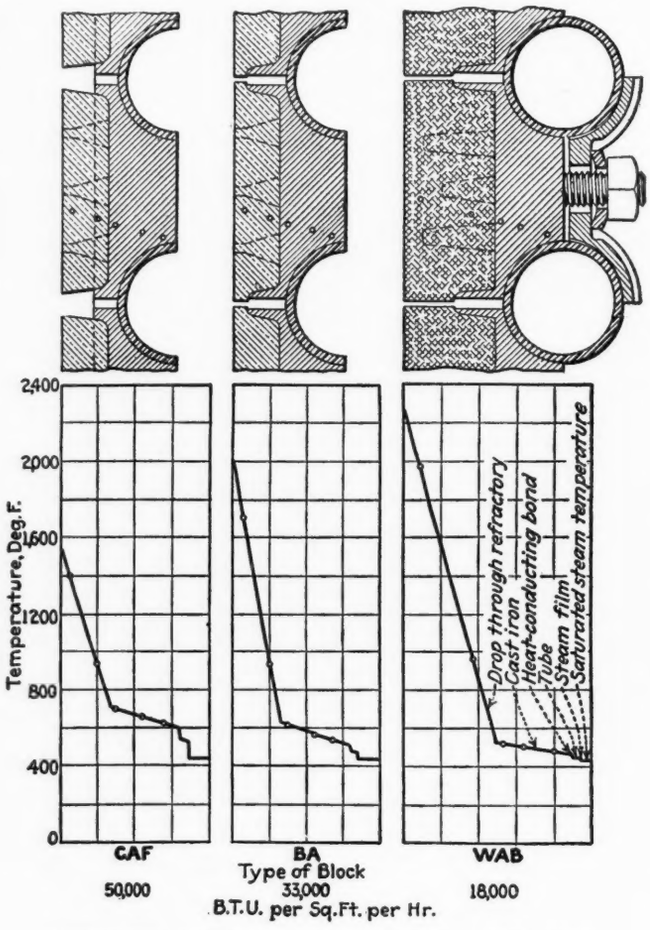
Most of the principles so far brought out apply equally well to solid or air-cooled refractory walls. Practically all modern furnaces, where water walls are not used, make some use of air cooling. Provision is almost universally made for the reduction of slag and clinker trouble by this means. The air-cooled surface, in some cases, is used to cover slag and clinker zones on the front, side, and bridge walls.

Increasing use of water-wall furnaces has been due to the demand for higher efficiencies and ratings and to a desire to get rid of troublesome maintenance of furnace brickwork. This object has been attained to a large extent, although it must not be assumed that the mere adoption of water walls means an end to all furnace troubles. The rate of heat transmission in water walls is extremely high. There is a tendency in some cases for steam along the side of the wall near the fire to blanket the heating surface and increase resistance to heat flow to a point where the tube failure threatens. If, in addition, the water is not absolutely soft, so that a slight layer of scale forms, trouble from tube failure is likely.

Reports from many of the leading central stations indicate that, under some conditions at least, the installation of properly designed water walls practically eliminates maintenance. One example is a large station in the East which was operated for a year with the loss of only one tube. Many who have studied the problem, however, are confident that the remarkable record of water walls does not mark the passing of the simple refractory wall. Refractory maintenance costs must reach a certain point before the additional investment in water walls is justified. There are many smaller installations operated at moderate ratings where the solid or air-cooled refractory wall is looked upon as a better investment. And there are, of course, innumerable installations where a combination is better than either alone.

In considering the relation of water walls to the maintenance problem, one should not overlook the fact that the use of water cooling in connection with stoker firing tends to reduce the maintenance of the stoker itself as well as that of the wall.

Water walls virtually remove any limits that refractories may have placed upon the rating and efficiency of the boiler. They also act as heat-absorbing surfaces of extraordinary efficiency. Thus, the apparent increase in first cost, due to their use, may be largely or completely canceled by these gains.

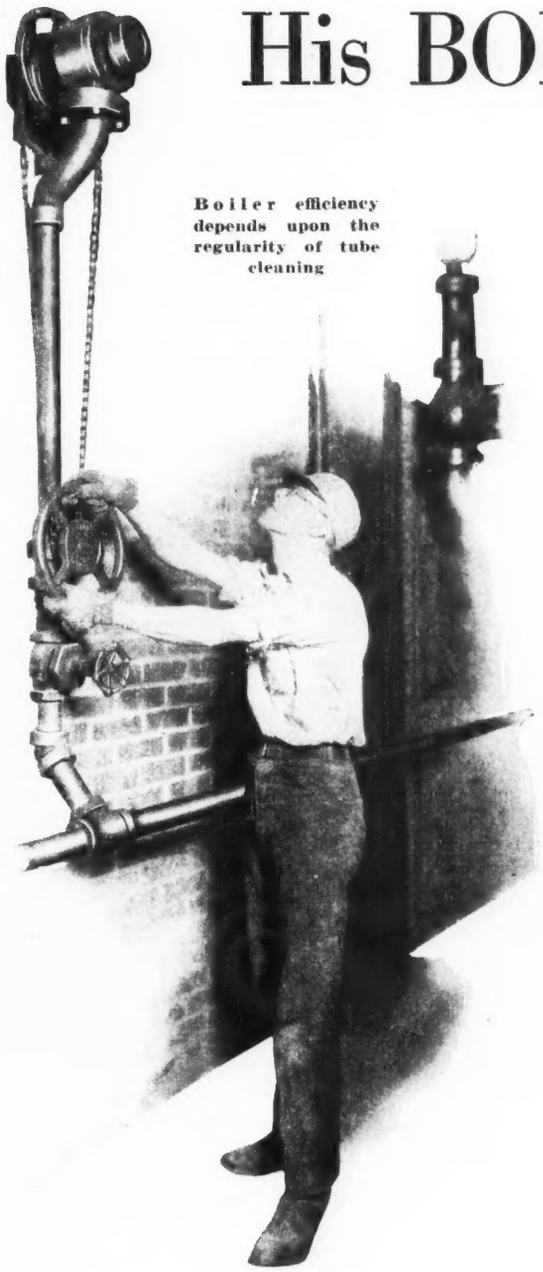


Temperature gradients through refractory faced water wall blocks (CAF block faced with silicon carbide)

It will be seen from these statements that the maintenance problem in connection with boiler furnaces is primarily one of designing and constructing for minimum total yearly cost. In some cases maintenance cost will be so high, and the improvements in design so great since initial installation, that it will pay to put in an entirely new furnace along modern lines.

The ENGINEER MUST KNOW His BOILERS

Boilers, like human beings, have their failings and idiosyncrasies; so the successful engineer must understand his boilers and must anticipate maintenance to obtain the most economical results



Boiler efficiency depends upon the regularity of tube cleaning

THE MAJOR PART of power plant investment is in the boilers and accessories supplying the boiler with fuel and water. This equipment is placed in the keeping of a chief engineer and his boiler room organization, with expectation that the machinery will receive operating attention sufficient to keep production at a high average, outage at a reasonable minimum, and depreciation to the usual charge against the capital account.

To meet this requirement, maintenance and repairs must be anticipated, material and men provided, and organized effort put forth to synchronize the upkeep of boiler, furnace, and attachments.

It is probable that the majority of boiler ills are due directly or indirectly to the quality of the feed water. In the larger plants, particularly those with water-tube boilers, where the evaporation may exceed 10 lb. of water per square foot of heating surface per hour, the feed water must be as nearly as possible free from impurities. A coating of scale $\frac{1}{8}$ in. thick, while not uncommon or particularly objectionable in a fire-tube boiler becomes a source of danger and results in increased maintenance when it is on the heating surface of a modern water-tube boiler with a high-duty furnace.

Sediment carried by the feed water, even when treated so that the resulting combination will remain in suspension, will be swept into the superheater tubes, and the resulting overheating will necessitate early renewal of parts which should be serviceable during the life of the installation. This difficulty the engineer must overcome by installing suitable stream purifiers or separators between the boiler and superheater. This purifier should be constructed in keeping with requirements applying to boiler parts.

The use of condensate or of treated feed water may cause corrosion in the form of pitting within the boiler. This action will be most pronounced in those parts subjected to stresses in the boiler manufacturing process, and if allowed to continue may result in the retirement of the boiler from service. The free oxygen and other gases carried by the feed water are responsible for the pitting, which may be eliminated by deaërating or deactivating or by a protective coating.

In case the feed water is contaminated with acids from industrial activities or from sewage, the corrosion which results is most likely to decrease the thickness of the shell plates, heads and tubes very uniformly and give the surfaces a glazed appearance. If the treatment to improve the feed water leaves an excess of sodium carbonate over the amount of sodium sulphate the plates at the seams where concentration can take place may be affected by intercrystalline cracking.

The engineer should be acquainted with the effect of various feed-water impurities upon the operation of the boiler.

The steel economizer section of the installation, whether of the integral or separate type, will feel most seriously the effects of poor feed water. The tendency of some elements to precipitate as the feed-water temperature increases the activity of included gases at low

temperature accounts for the scale in some economizers as well as for the pitting in others.

Moisture that reaches the surfaces exposed to the products of combustion, whether as the result of leakage from a tube, a riveted joint, or a soot blower, causes rapid corrosion, while the surface exposed to steam escaping from a superheater is cut as if in the path of a sand blast.

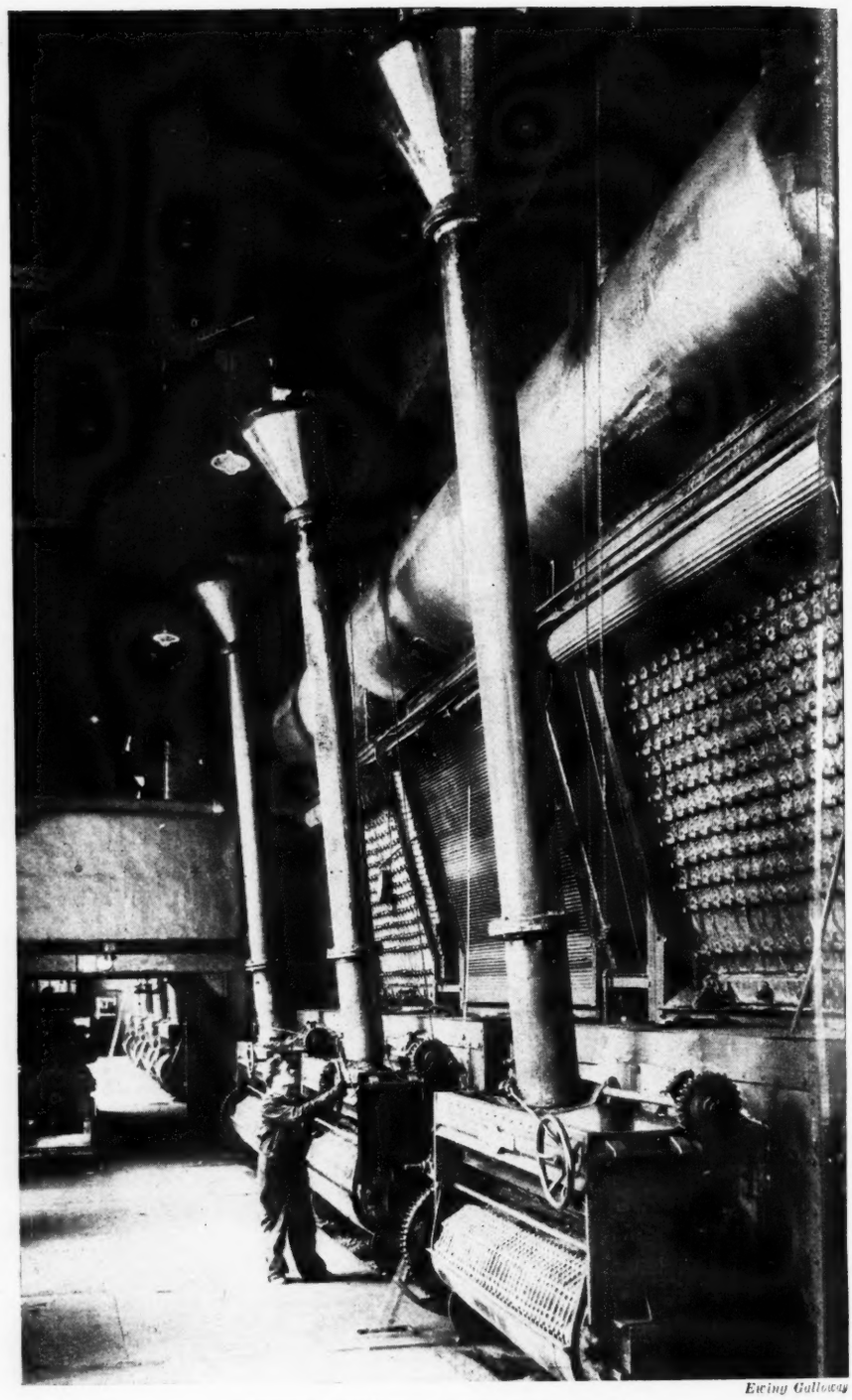
To an extent, fusion welding has been used successfully in preventing leakage from boiler joints, but the work must be done by a welder experienced with low-carbon steel. The parts to be united by welding must be supported by an other suitable form of construction, such as riveting, threading, or taper fitting, and the welding depended upon to secure tightness only. But a leaking seam or leaking nipple should not be tightened by welding until a thorough investigation develops the fact that the material is not damaged by cracking or seriously weakened by corrosion.

The girth seam of horizontal tubular boilers and of Scotch marine boilers has been the source of great annoyance and expense on account of leakage. Fusion welding if properly done should be a suitable repair if close examination proves the plate and rivets are sound. The practice of welding blow-off pipes or any other thin wall should be discouraged, for quite frequently the wall of the pipe or nipple is weakened by the depth of the penetration of the weld.

The distorted water tube is frequently a cause of worry to the engineer whose experience may have been confined to straight-tube boilers. He overlooks the fact many popular water-tube boilers have nothing but bent tubes. The mere fact that a tube initially straight has changed its shape, as the result of exposure to high temperature and the contraction which takes place as the tube cools, should not lead to the conclusion that the tube is not safe to operate. However, a seriously warped tube may have slipped where expanded in the tube sheet and may need re-expanding to insure tightness, or the stresses resulting from the change in shape may have produced circumferential cracks in the wall of the tube near the tube sheet. Such tubes should be renewed.

Tubes supporting the baffle tile must be of proper shape to serve that purpose. Frequently it is more economical to replace a sound but crooked tube than to suffer the loss in fuel economy resulting from poorly fitting gas baffles.

Water tubes often incase the combustion chambers of pulverized-coal furnaces and also act as support for the refractory and insulating material employed to confine the heat and direct the path of the gases.



Ewing Galloway

Eternal vigilance is the price of efficient and satisfactory boiler performance

Some of the water-wall tubes have fins welded to the tube longitudinally. High furnace temperatures may cause burning and cracking of water-wall fins, which may continue to the extent of piercing the tube wall and necessitating renewal. However, overheating and cracking of the fin may not impair the usefulness of a tube provided warping does not follow to such a degree that the furnace wall is deprived of the support needed to hold it in proper position.

The necessity of removing a defective boiler tube when there is no new tube in stock is a condition which may confront the operating engineer at any time if the production of the plant depends upon the use of the boiler having the defective tube. For that reason at least one of each shape should be kept in stock.

Assuming the tube is not one necessary to support the baffle or the furnace wall, holes in the tube sheets may be closed by the use of tube-hole plates, caps, or quill tubes, as an emergency measure. A quill tube seems best adapted for the purpose, as it can be made from a section of an old tube by anyone experienced with a hammer and anvil. Of course, a standard length tube should be put in as soon as possible, because the quill tube is likely to weaken as the result of corrosion. Use of the quill tube as an emergency measure is of equal advantage in superheater, economizer, and water-wall headers.

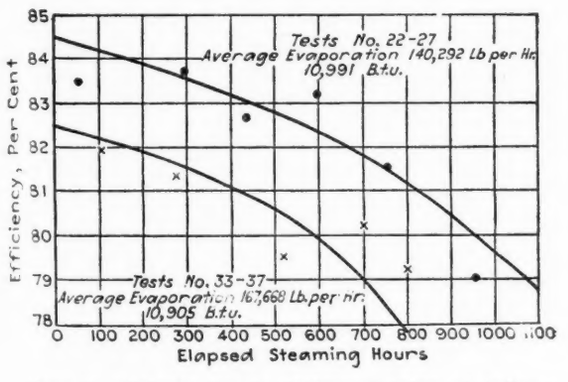
In the days of poor feed water boilers were cooled down twice a month for internal cleaning. Modern feed-water treatment has eliminated the work, loss of production, and expense of cooling boilers so frequently to remove internal accumulations of sediment. Another problem having a greater influence upon fuel economy has appeared in company with the high rates of combustion now encountered. The accumulation of slag or fly ash upon the heating surfaces acts as an insulator to prevent heat absorption and also acts as a barrier to the flow of the products of combustion through the gas passages. So boilers must now receive external cleaning even if internally clean. The effect of soot deposits is shown in the two graphs on this page.

Soot blowers placed in the furnace to remove the crust of non-combustibles carried by the fuel should receive careful inspection while a boiler is out of service. Nozzles should not cause escaping steam to impinge upon tube or shell surfaces of the boiler. If the nozzle headers are of the rotating type they must be maintained so that their rotation will occur as intended. Otherwise, the efficiency of the apparatus is reduced and the probability of the steam from the nozzles impinging upon the shell or tubes is increased. Nozzles should be inspected for wear, and the control valves for leakage.

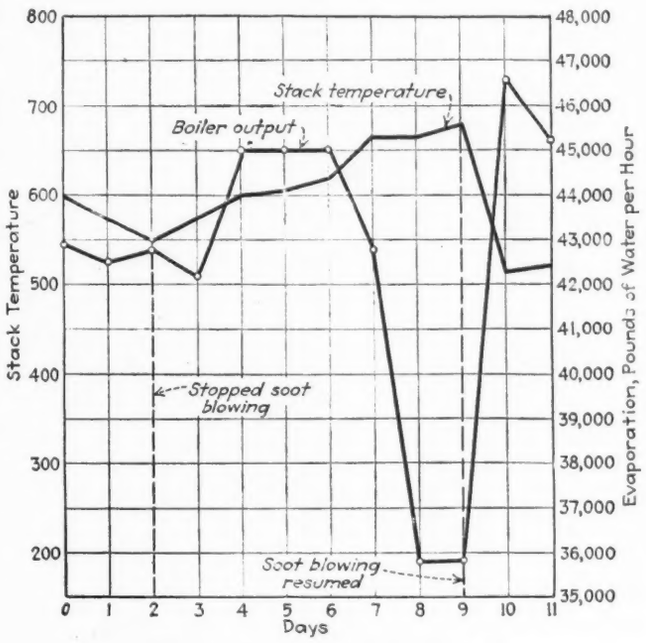
Although the use of a high-pressure stream of water to wash the accumulation from the heating surfaces of boiler, economizer, and superheater while the unit is in service may appear a questionable practice, it is being followed in many modern plants with success.

That there may be a double check on the water level it is customary to provide a second water column, in or under that one is connected to each head of the boiler drum. Small openings in high-pressure valves and pipe connections are easily obstructed, so one of the water-level indicators may become inoperative. If blowing that column does not remove the obstruction so that the glass gage will register the correct water level, the boiler should be taken from service rather than operated while depending upon one glass gage. A boiler should not be considered serviceable unless both water columns are in working order. A high-pressure boiler operating at 300 or 400 per cent of standard rating will boil dry in 30 or 40 min. and any error in judgment pertaining to the water level and operation of the feed pump is likely to be costly.

The engineer of an obsolete boiler plant is confronted with a serious problem. He is impressed with the more



Drop in efficiency due to fouling of tubes of boiler burning Kentucky coal



Effect of soot blowing in stack gases

favorable record of fuel economy shown by the modern power plant across the way and seeks by every means within his reach to eliminate the waste of which the old plant is guilty. But the cost of power produced refuses to descend to the desired level, because the old equipment was not built to compete with modern installations.

With the best intentions and the greatest effort, and with the interest of his employer at heart, many an engineer in antiquated plants is trying to obtain increased economy at the expense of large maintenance costs, extra expense for improved auxiliaries, and unusual labor items. The owner of the plant has charged its cost to depreciation and obsolescence in his capital account, and so feels the operation of the plant is building up a surplus, although, in fact, each day it is continued in operation creates a deficit compared to the cost of producing a similar quantity of power in a plant of modern equipment especially selected for local conditions.

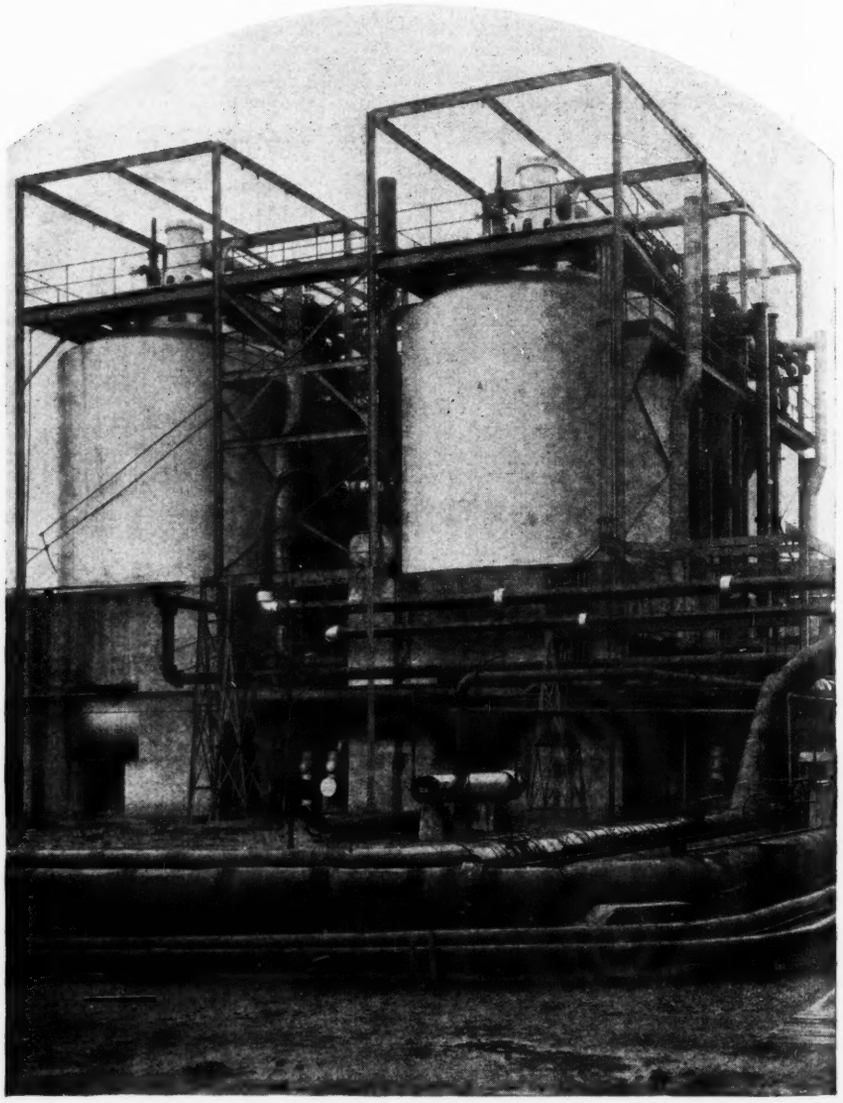
It is possible that the old plant no longer carries interest and depreciation charges, so the various items of power plant operating expense are the only ones considered in determining the cost of power produced.

The new plant must carry interest and depreciation charges, but in many instances the greater efficiency of a new installation will provide ample margin to carry whatever charges continue against the old plant as well as its own interest and depreciation and, besides, pay a handsome dividend on the investment, providing the engineering organization that prepares the plans and specifications for the new plant is experienced in the work and has the complete coöperation of the plant engineer.

Still, whether the equipment be old or modern, the engineer must know his boilers.

Keeping the

FEED WATER FIT



Sedimentation tanks of world's largest hot-process water softener—capacity, 420,000 gal. per hour

THE FEED-WATER system is a prime factor in the maintenance problem, but not because of the maintenance required by the system itself. While appreciable, this does not compare with that often demanded by economizers, boilers, and furnaces. Yet the importance of a feed-water system in the maintenance problem is very great, because the purity of the feed supply has a marked effect on the life, reliability, efficiency, and maintenance of other equipment.

This article will therefore approach the subject mainly from the angle of the effect of feed water handling on equipment maintenance, with incidental attention of important points in the maintenance of the feed-water system itself.

The feed-water system may be divided into two parts. One is the feed system proper, which handles the whole volume of feed water delivered to the boilers. The primary equipment to be considered here includes the hot-well pump, open heater, deaërator, feed pump, closed heaters, excess-pressure regulator, feed-water regulator, piping, and miscellaneous valves.

The other part is the make-up water system. The amount handled by it varies from less than 1 per cent of the total feed in some of the more modern central stations to nearly 100 per cent in the extreme case of an industrial plant supplying steam to process where the condensate is not returned.

In an imaginary power plant with zero make-up, and without oil contamination from reciprocating machinery, dissolved gases, chiefly air, would constitute practically the only impurity. This condition is approached in central stations with small make-up supplied by evaporators. There the major impurity is dissolved gas in the feed water.

It is well known that dissolved oxygen is a primary cause of corrosion, and that dissolved CO_2 accelerates corrosion.

For that reason extraordinary precautions are taken to prevent leakage of air into all parts of the feed and vapor systems operating at pressures below atmospheric. In addition, most central stations provide for the elimination of oxygen by special deaërators, or by open heaters of the deaërating type.

The feed system should be checked at regular intervals by a chemical test for dissolved oxygen. When this exceeds the concentration prescribed by experience the operation of the deaërator should be checked and the system searched for leaks. Air leaks can be located by sampling water or vapor at various points in the piping system and testing the samples for oxygen.

There are two general methods of dealing with the impurities brought into the system through the make-up. One, involving little equipment, is to introduce chemicals directly into the make-up, or into the boiler, and take

care of sediment and other reaction products by blowdown.

This method of treatment fell into bad repute after many years of unintelligent dosing with various nostrums. It is now possible, however, to control such treatment scientifically by the condition of the boiler water, and this method is to be recommended in many cases.

In general, there has been a swing in recent years toward eliminating impurities before they reach the boiler. An obvious method of attack, and the most thorough, is to distill all the make-up water. This is the usual procedure in central stations, where the percentage of make-up is small. Because of the high capital charges it is generally considered not commercially feasible with the very high percentage of make-up found in some industrial process plants.

Two systems of feed treatment are commonly found in such plants. One is the lime-soda process (hot or cold), in which lime or soda, or both, is added to the water, and in which most of the hardness is precipitated and drawn off as sludge before the water reaches the boiler.

It is essential that systems of this sort be properly controlled. Continuous systems are provided with automatic proportioners for the chemicals, but the treated water must be tested at intervals to get data for adjusting the chemical feed to changes in the raw water. Similarly, with the batch system of cold lime-soda treatment, the dosage for each batch should be determined by chemical test.

In recent years trisodium phosphate and other sodium phosphates, sodium aluminate and other chemicals, have found increasing use in the treatment of feed water. The fields for these various chemicals, their advantages and disadvantages, are a complex subject on which much has been written, and into which it is not possible to go in the limited space here available.

Distinctly different in principle from these chemical methods of feed treatment is the zeolite system. There are many zeolites, varying in chemical composition, appearance, rate of action, and other properties. They are all alike in their general action. They are sand-like substances, insoluble in water, and containing sodium in a form which will automatically exchange with the metallic element in the hardness of raw water.

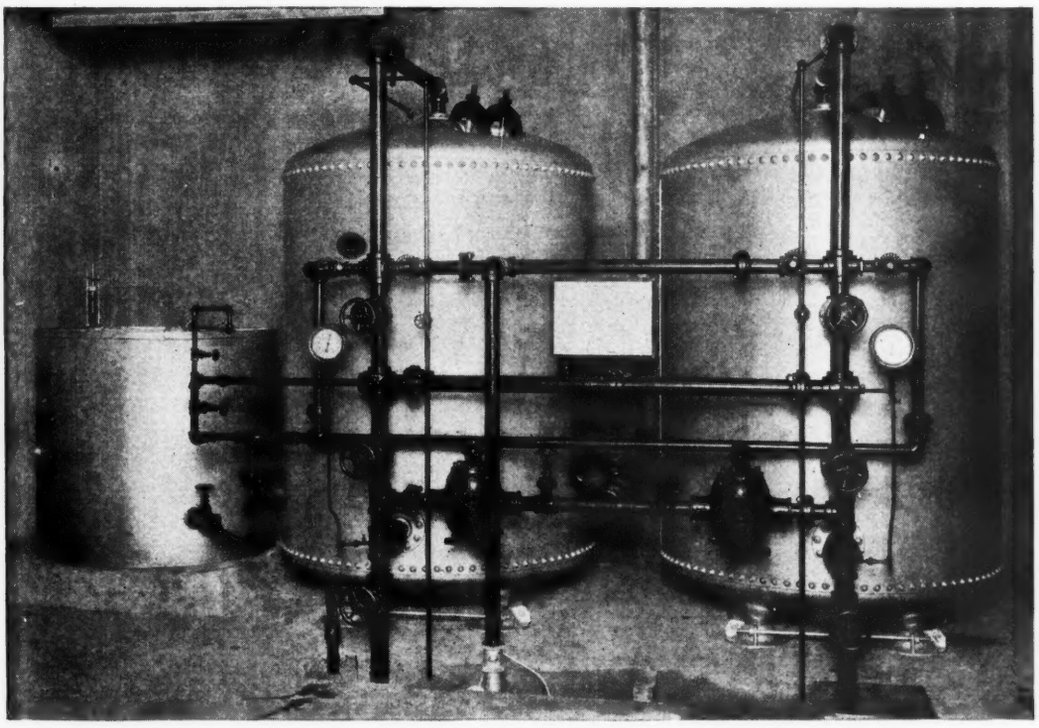
Thus when water containing calcium carbonate is passed through the zeolite bed, the calcium carbonate is changed to sodium carbonate, and the calcium becomes bound up with the zeolite compound. In the same way, calcium sulphate is changed to sodium sulphate.

For all practical purposes this reaction is complete. Water treated by zeolite softeners has no visible reaction on a soap solution, and is said to be of "zero hardness." It is entirely non-scale-forming. There are left in the water, however, molecules of sodium salts equal in number to those of the original "hard" compounds from which they were formed.

While the sodium salts are completely soluble at all temperatures, and cannot form scale, they gradually concentrate in the boiler. This continual delivery of sodium salts will eventually lead to priming if the concentration is not kept below the danger point by blowing down the boiler.

The resulting heat loss may be largely avoided by using a heat exchanger with continuous blowdown. Decision as to the proper system to use for any set of conditions should preferably be based on the advice of a disinterested expert.

Operation of a zeolite system involves "regeneration" of the zeolite after a certain quantity of water of given hardness has passed through the bed. In regeneration salt brine is passed through the zeolite bed, reversing the original softening reaction. The brine replaces the sodium in the zeolite molecules and removes the hardness. After regenerating, the remaining brine must be drained



Double-unit zeolite water softener permits of operation of one unit while the other is being regenerated. The brine tank is shown at the left

off and the zeolite washed with softened or raw water. It is then ready for a new cycle of softening.

In addition to softeners, a filter and tanks for settling and coagulation may be necessary where the water contains mud, organic impurities, etc. The method of operation of these systems should be laid down by an expert and controlled by tests.

While the output of an evaporator far exceeds, in purity, that of any chemical or zeolite system, a small quantity of impurities will be carried over in practical operation. Operation of evaporators at high ratings may lead to priming. In this way more than a trace of impurities may find their way into the vapor.

In any case, the concentrated solids left in an evaporator must be removed at regular intervals. Soluble salts are easily removed by blowdown, continuous or periodic. Scale-forming substances gradually accumulate on the evaporator coils, and cut down the capacity until it is necessary to stop the unit for coil cleaning. Evaporator units are generally installed in groups, so that one may be shut down for cleaning without impairing the operation of the station. A common method of coil cleaning is to induce sharp changes in temperature by alternate application of steam and cold water. This produces changes in the coil shape, which ordinarily cracks off most of the scale.

Under some conditions, and with certain waters, scale removal by this method may be incomplete, so that additional hand cleaning is required. To avoid this there has been a growing tendency to treat the evaporator feed. For this purpose zeolite softeners are frequently installed. Thus the necessity of scale cracking is removed, while the blowdown of the evaporator takes care of the accumulating soluble impurities.

A survey made by the Prime Movers Committee of the N.E.L.A., and reported in 1929, showed that of twenty-four plants using evaporators, ten pretreat the evaporator feed. Of these ten, six use zeolite softeners, while four report the use of a chemical treatment before the evaporator.

The important thing to remember about practically all systems of feed-water treatment is the need for intelligent control. A few comments may be made on the maintenance of the feed and make-up systems themselves. In lime-soda softening plants it is particularly important that the orifices of chemical proportioning devices be kept clean, and that all mechanism of the proportioning devices be kept in good working order. With zeolite softeners and sand filters the design should provide for periodic loosening of the filter bed to avoid clogging and at the same time prevent the loss of valuable filtering or zeolite material.

In evaporator design all interior parts should be accessible and easy to repair. It should be possible to remove individual coils without dismantling the evaporator.

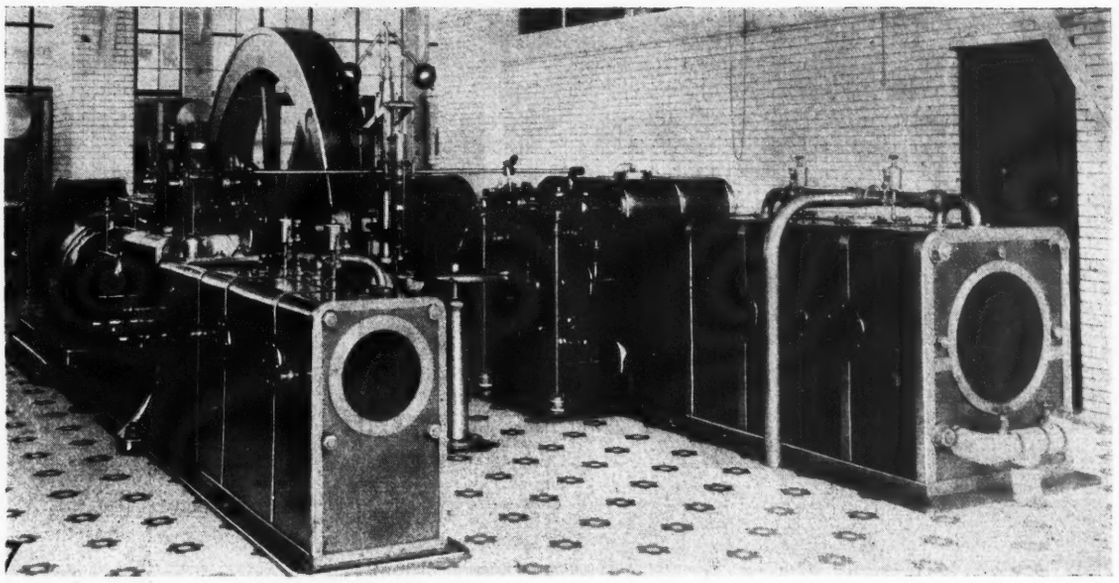
With certain types of evaporator feed water, or where the temperature differences available for cracking are insufficient, it may be necessary from time to time to give the evaporator coils a special cleaning, using chemical compound and boiling out the evaporator.

In the main feed system trouble is sometimes experienced from the pump where attempt is made to lift water by suction at temperatures above 160 deg. or where intake water at higher temperatures comes to the pump under insufficient pressure. This not only cuts down the capacity and efficiency of the pump, as a result of steam binding, but also may lead to pitting of the impeller in the case of centrifugal pumps.

At the Mad River Station, whose operation for two years was reported in *Power* of July 15, 1930, two of the three 500-gal. boiler feed pumps are motor-driven, and one is steam-driven. Each pump is inspected internally twice a year. At these inspections attention is given to adjustment, appearance, and minor repairs. It was found desirable to put oil deflectors on the outboard bearings of the motor-driven pump, and water deflectors on the inboard bearings, to prevent water's flowing into the bearing oil pump lines.

Motor-driven condensate pumps at Mad River gave considerable trouble during the start-up of the plant, owing to impeller cavitation and erosion. The impellers lasted twelve weeks. A liquid level controller installed on the hot well prevented further trouble. Shaft and impeller assembly were redesigned to prevent oxygen contamination of the condensate.

Experiences of many central stations, as reported by the N.E.L.A. Prime Movers Committee, indicate that certain protective coatings have real value in preventing corrosion of pipes, economizers, boiler drums, and boiler tubes. Such coatings may also be applied to the interior of closed heaters, including house-service water heaters. Maintenance required by excess-pressure regulators, feed-water regulators, valves, piping, and closed heaters is largely determined by the effectiveness with which the feed treatment is controlled. Impurities and scale-forming substances in the water tend to cause trouble with all of this equipment. Routine inspections and cleaning and the usual adjustments suffice, with pure water and good equipment.



Maintaining the Original Economy of Reciprocating Engines

Scheduled maintenance will enable a steam engine to hold its original economy —depreciation, then, consists almost exclusively of obsolescence brought about by improvements in design or by inadequacy

PARADOXICAL as it may seem, a steam engine seldom wears out; yet a maintenance program is more essential for it than for some short-life machines. This is not because of the outage tendency of an engine when adjustments and repairs are not corrected, for an engine will continue to function despite the fact that it is in a decidedly run-down condition; indeed stability of operation will persist even though an engine be in such physical shape that its steam consumption has increased by 100 per cent. In fact, it is not exceptional to discover a reciprocating engine whose initial steam rate of 30 lb. per kilowatt-hour has been increased to 50 lb. without the engine's displaying any marked misadjustment.

Increase in steam consumption results from: Improperly set valves, worn valves and seats, scored cylinders, and worn piston rings and leaky stuffing boxes. In addition, increased mechanical friction, usually from bearing wear, will affect the steam rate, but not markedly.

Years ago when the steam engine indicator was brought into commercial use various engine experts obtained a most attractive income by going from plant to plant offering to reset the engine valves and to take part of the resultant savings in the coal bill as payment for their services. Remarkable reductions in steam consumption were obtained, and this led to a keen interest in the indicator by operating engineers—until a man could not substantiate his claim of being a high-grade engineer except by the ownership of an indicator and a planimeter. The crest in indicator enthusiasm was succeeded by a period of lack of interest which extends up to the present. As a consequence, but few operating engineers own an indicator or can intelligently interpret the reasons for peculiarities in the diagrams.

This is unfortunate; outside of frictional losses, various defects that influence steam consumption are most easily detected through an examination of indicator diagrams taken from an engine.

Even slow-speed engines suffer from worn valves and worn valve seats. Although some corliss engines have steam valves partly balanced, the majority of machines employs an unbalanced type. With 150 lb. steam pressure executed on a bar of, say, 30 in. length and 3 in. width of seat making a total bearing pressure of 13,500 lb. it is not surprising to find both the valve and seat showing wear, especially where lubrication methods are indifferent.

With high-speed engines having sliding valve surfaces, wear occurs more or less in proportion to the amount of unbalanced surface, valve velocity, and degree of lubrication. Such wear permits of steam leakage throughout the power and exhaust strokes. Although a groove 0.01 in.

deep may seem trifling, loss through it will raise the steam consumption markedly, depending upon the number of grooves, their width and depth, and the engine speed and steam pressure. Such leakage is especially large with valve designs wherein the exhaust port is separated from the steam port by a narrow bridge. Increases of steam consumption ranging as high as 100 per cent are found on ill-maintained engines.

More modern designs of uniflow engines with poppet valves do not suffer valve wear to the extent that do slide-valve engines. Poppet valves do not slide in their seats; so leaks from sliding wear do not occur. But such valves, when indifferently designed, may warp by reason of improper distribution of the metal. Either one of the valve disks may warp to an extent that it fails to contact at all points of the seat, or the valve body may elongate in such manner that the distance between the valve disks becomes greater than the distance between the seats of the housings. An unfortunate thing about this situation is that a valve may leak when hot and be absolutely steam-tight when cold, or a change in steam temperature of even 50 deg., brought about by variation in the superheat, may distort the valve.

To avoid these difficulties engine builders have adopted valves that permit of changes in dimensions without leakage. This change may be telescopic in nature or one of the valve disks may be made flexible.

Maintenance Schedule	Engine No.		
Part	Time Interval	Date	Next Date
Cylinder bore, inspect	1 year		
Piston, pull for inspection	2 years		
Valves, check for leakage	6 months		
Valve gear, readjust.	6 months		
Governor, inspect for wear	3 months		
Governor, check overspeed	Weekly		
Safety Governor, check action	Weekly		
Crosshead shoe, adjust.	6 months		
Rod Packing, withdraw	2 years		
Rod bearings, adjust.	6 months		
Crank pin, check alignment	2 years		
Main Bearings, check	1 year		
Shaft, Check for alignment	2 years		
Separator, see if clear	daily		
Traps, see if working	daily		

Fig. 1 — Maintenance schedule followed in one department-store plant

Broadly speaking, it can be assumed with some certainty that all valves are inclined to leak after some period of operation, the duration of which depends upon the design of valve and upon the lubrication method followed. As a consequence, almost any engine will retain its initial steam rate for, say, two years, after which time steam consumption steadily increases. An engineer cannot afford to ignore the mounting steam rate until the wear is such that the valve becomes noisy. Because that noise is usually in the gearing rather than in the valve itself, it is safe to say that long before gear can be termed noisy the valve is in need of attention.

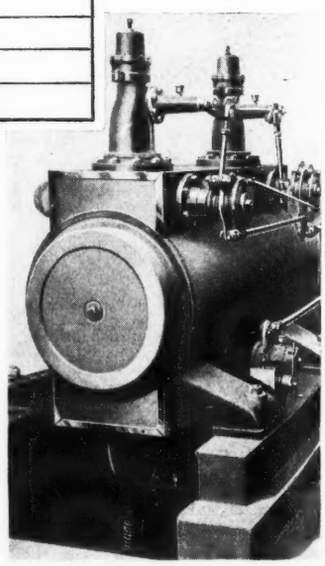
Warning signs of valve wear are: increased steam consumption; inability to carry load with the usual cut-off or valve travel; and a distorted expansion line on the indicator diagram.

The best method of preventing leaky valves is through the use of a steam engine indicator. A leaky valve will make itself evident by the shape of the diagram, and the engine should be overhauled at the earliest possible date.

It is possible to detect a leaky valve by turning the engine to a point where the valve covers both steam ports. If the indicator cocks on each cylinder end and the throttle valve are opened, steam will pass the leaky valve into the cylinder end and out of the cock connected to that particular end. It must be remembered that this method is not infallible, for even though a valve is tight at mid-position, it may leak at other points of travel. But because the seal is more important after the valve has cut off, mid-position is the best point to employ in this test, which, after all, is a makeshift.

Slide valves are more prone to cutting than those of corliss or piston types; but the remedy is more difficult. An inexperienced mechanic who attempts for the first time to re-plane a steam chest seat and refinish the valve is in for a world of trouble. To do the job properly calls for the grinding or lapping of the valve and its test on a surface plate. Unfortunately, few valves are so refinished, so the majority of slide valves leak.

Regardless of the type of valve, cost of removal or refinishing is slight compared to the saving in steam. A 500-hp. unit that, through valve wear, increases its steam rate but one pound, may use $500 more coal yearly than it should; what an increase of 25 lb. per horsepower-hour means is apparent. The steam rate of a 225-kw. corliss engine over a period of 16 years is shown in Fig. 2.



When an engineer finds that the engine valves wear and that the bearing surface is dry, he should set about to improve the lubrication methods. Hydrostatic lubricators are frequently placed so close to the steam chest that the oil drops have no chance to mix with the steam, but flow down and pass out through the separator or throttle-valve drain. To insure successful oiling of the valve and cylinder, the hydrostatic lubricator should be connected at least two feet above the throttle valve, and the lubricator's steam dome should be connected to the steam line at least 4 ft. above the oil-feed connections.

When large flat or rotative valves are used, as in rolling mill and hoist work, dry valves can be corrected by applying an oil feed to the valve seat through a connection from a mechanical lubricator.

Worn bushings and pins in valve gearing and governor mechanism frequently so disturb the setting of the valves that the entire cycle of events is altered. Indica-

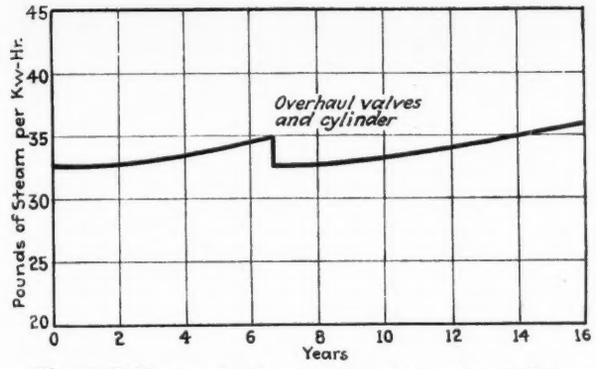


Fig. 2—Influence of valve wear on steam consumption

tor diagrams frequently reveal unequal cut-offs and different releases and compressions in engines where the engineer had not been able to understand why the engine was using so much steam.

Safety is also involved in worn valve gear and governor pins. The engine should be examined at least monthly for signs of excessive play in the governor and gear; that precaution may be the means of avoiding a wreck.

Governor pins, especially, should be examined for wear, and if replacement is necessary it is far preferable to obtain new pins from the governor builder rather than from a local machine shop. A recent engine wreckage was traced to a soft-steel governor pin which had been made at a local shop. The wear was so rapid that long before the engineer would have inspected it in the ordinary course of maintenance, the pin gave way, and the engine overspeeded and wrecked itself.

Another point of wear is the cylinder walls. When the cylinder is made of soft cast iron it is not unusual to find rapid wear, especially if the rings have been made of a harder iron. Slight wear, provided it is more or less uniform and free from scoring, is not serious. Usually, though, this will cause the rings to wear rapidly at their sides, and also to wear the sides of the ring grooves.

Cylinder scores, however, are serious, and when pronounced must be removed by reboring. These scores are frequently due to poor lubrication: The cylinder becomes dry at local points, usually at the bottom of the barrel, and the rings cut out enough of the dry metal to cause severe leakage. If the dry surface is of some extent, the frictional resistance may be enough to slow down the engine.

Dry cylinders can be eliminated by the use of force-feed oil lines to the cylinder barrel. In a uniflow engine the feed should enter at some distance from the central exhaust belt, to prevent the rush of steam from sweeping the oil drops out into the exhaust line. Modern engines require modern oiling devices, which has led to a general adoption of mechanical force-fed oilers. Wear of the bottom crosshead shoe causes a lowering of the piston rod, so that the rod scores the stuffing-box packing. Guide wear should be compensated for each time the engine is given a general overhauling; excessive wear can be detected during weekly routine inspection by jumping the crosshead with a small bar.

Wear on the stuffing box makes itself apparent immediately, and the disagreeableness of escaping steam will prompt the average engineer to adjust the parts at once. In case of metallic packing, a little blow-by is to be expected when the engine starts up from cold. But the rings should seal the box in a few minutes. If the leak persists there is no remedy other than to dismantle the stuffing box and insert new rings. In most cases ring wear is due to poor cylinder lubrication, and under extreme conditions an oil feed should be applied to the stuffing box. Sometimes leaks are due entirely to error in placing the rings in the holder.

Connecting-rod bearings, especially the one at the crankpin end, require taking up. Frequency of this adjustment depends upon load conditions. Hot bearings usually are traceable to misalignment of the crankpin. The only remedy is to replace the pin, proceeded by a checking up of the crankpin bore alignment with the shaft.

The shaft, while it seems a part that should be free from defects, justifies a periodical examination for scored journals and for fractures at the junction with the crankarm.

Main and outboard bearings will settle out of alignment, so during overhaul the shaft should be tested for level and for alignment with the frame.

Engine safety devices, including the engine governor and the overspeed governor, or safety, should be examined at stated periods, for overspeed devices may stick if not tested occasionally. Other accessories, such as the steam separator, the cylinder drains and traps, should be kept in operating condition at all times. A scheduled inspection should not be required, for these parts should be examined daily in the course of the routine work.

No one can outline with any degree of accuracy the frequency with which the engine parts should be examined. However, for usual operating conditions the schedule in Fig. 1 should be satisfactory. The important thing is that inspection should follow some kind of a schedule.

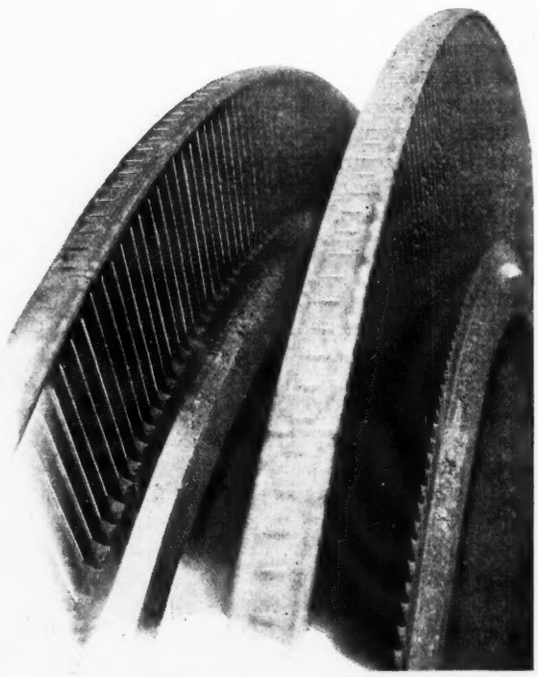
There is, in case of an old engine, the question of overhaul or replacement. If the unit has a high steam rate due to limitations in design, serious study should be given to the possible advantages of newer types. Engines that use 35 to 50 lb. of steam per kilowatt-hour can hardly justify their continuance in service, since modern machines have rates as low as 26 lb. when operating non-condensing. Only when all, or the major part, of the exhaust steam is used in some process is the inefficient engine worth it's room space. In some instances it is possible to merely replace the old cylinder, retaining the generator, the shaft, frame, and other parts.

Turbine Outage

Reduced by

Regular Inspection

Power plants, both industrial and utility, are called upon to deliver a service that must be continuous and uninterrupted. Such a service cannot be rendered if main and auxiliary turbines are neglected to such an extent that forced shutdowns occur



Blading of a large turbine, showing erosion and corrosion

BLADE, thrust bearing, and shaft seal failures have been frequent causes of forced shutdowns. Failures such as these occurring when the unit is in operation can generally be counted upon to cause damage to other parts of the turbine. Inspection of the records kept by many plants that follow a regular inspection routine has disclosed that defects have been found which if allowed to go unrepaired would certainly have resulted in failure during operation, with probable serious results. Along with these more important maintenance incentives, of safe and continuous operations, is improvement of turbine efficiency.

To keep a turbine in good operating condition it should be completely overhauled and inspected after from six to eight thousand hours of operation or about once a year. This requires some planning, particularly where there are a number of units, in order to always leave enough capacity in service to carry the plant load. In central stations it is generally considered necessary to keep ready for service enough capacity to carry the load in case one unit has to be shut down. Thus overhauling is generally scheduled during the summer, when the load is light. An overhauling schedule is shown on page 348 The dotted line indicates last year's load and the solid line above shows the estimated load for the current year. The station capacity is 138,000 kw. The capacity available with various units down for overhaul is shown by the heavy line, and the dot-dash line shows the capacity left, if the largest remaining unit has to be shut down, and is at all times above the expected load.

Industrial plants do not, as a rule, have enough excess capacity to follow this practice. Overhauling, however, can often be done during inventory or vacation periods, when the factory is practically shut down, or else operation continued without spare capacity.

The time necessary for overhauling varies widely with the amount of work to be done and the size of the turbine. If the spindle has to be returned to the factory for reblading or other work, the unit may be out of service from six weeks to two months, but if no parts have to be replaced the inspection period is much shorter. An average overhauling period is about four hundred hours.

Time will be saved if, during the year, a record is kept of the work to be done on the turbine when it is shut down for repair. Such a record can be compiled from notes made by the turbine room engineer on the daily log sheet, or from weekly inspections. As the various jobs are finished they can be checked off on the record, thus making it difficult to overlook work scheduled to be done.

The annual overhaul should be complete and thorough, and all parts of the turbine inspected even though they have given no trouble. Particularly is this true of the blading, for although presence of corrosion, erosion, and scale can generally be predicted from performance data, thorough inspection is necessary to find cracks and blades loose at the roots or shrouding. If binding wire is used the silver soldering ought to be gone over to see if it has cracked loose. Cracked blades should be replaced and loose blades tightened, as further operation in this condition may result in a serious failure. Slight erosion or battering of the blades can be repaired by silver soldering, but if extensive the rotor is best rebladed and an investigation made to determine the cause.

Shaft seals need inspection for cracked runners, cor-

rosion, and wear. If of the labyrinth type, clearances should be checked and the results compared with the measurements made when the unit was last inspected. The erosion or wear of the impeller of water type shaft seals in some cases makes its replacement necessary about every two years, and for this reason its inspection ought not be neglected.

It is not likely that any work will be necessary on the bearings, excepting the thrust bearings, which may require some attention. They need, however, to be cleaned and any rough spots scraped smooth. Oil passages and pipes both to and from the bearing also require cleaning. In fact, the entire oiling system should be gone over and cleaned, including the oil coolers.

The governor should be dismantled and inspected, knife edges and V-blocks cleaned and if in bad condition polished, and lost motion in the governor linkage eliminated. Relay valve pistons ought to be examined and cleaned and packing that might cause sluggish operation should be replaced.

Throttle and stop valves generally need to be examined and reground if known to leak or if the seat or disks are marred. Valve stem packing best be renewed and the dashpot on the turbine stop valve cleaned and inspected. The emergency stop mechanism should be inspected and tripped by hand to test its action.

Before the turbine spindle is removed to inspect the blading, radial clearance must be measured and recorded. These measurements, when compared with those made when the unit was installed, can be used to determine whether there has been any serious cylinder or shaft distortion.

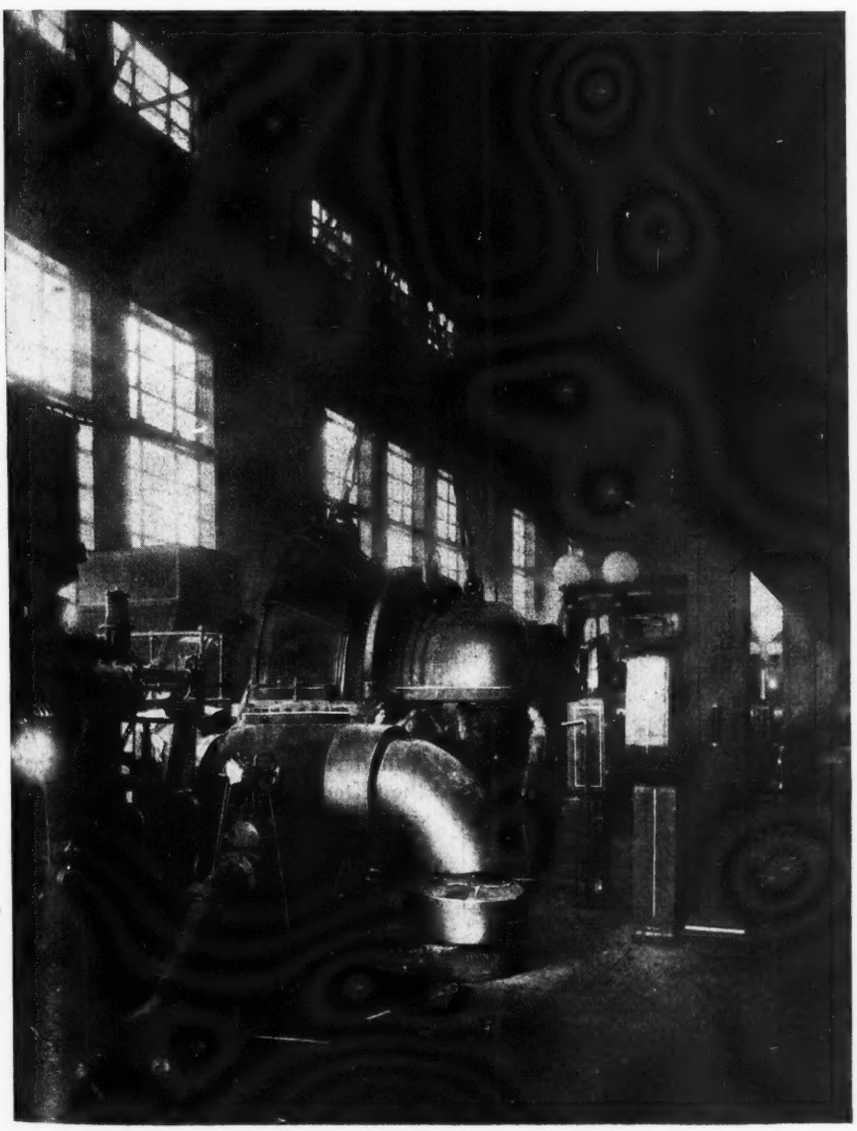
When the unit is assembled the clearances ought to be measured in order to have a record of the condition in which the unit is left. Clearances should also be measured at the coupling between generator and turbine to determine the degree of concentricity, and the generator bearings adjusted until the shafts are concentric within at least .002 to .004 in., where the coupling is of the flexible type. If the turbine is of the reaction type it is advisable to determine the cold center position of the spindle and then set it a few thousandths above center. The cold center position and the moves made to determine it ought to be recorded for future reference.

Before the unit is again placed in regular operation the governor and overspeed trips should be operated and set to shut the turbine throttle or stop valve at the speeds specified by the manufacturer.

A certain amount of maintenance is necessary in addition to that during the annual overhauling period. Many operators grind the stop valves at intervals of from three to six months to keep the valve steam tight. Oil coolers have to be cleaned at more or less regular intervals. The cleaning period is best determined by observing the inlet and outlet oil temperatures. The generator air cooler also has to be cleaned, but the interval between cleaning depends upon the dirtiness of the cooling water.

Pressure and temperature indications of instruments normally installed with the turbine can be used to foretell pending trouble. Thermometers in the oil discharge from bearings will indicate abnormal temperatures if the bearing becomes dirty or out of adjustment or if the oil flow to it is insufficient. Pressure gages at the shaft seals will indicate, by comparison with previous readings taken at the same load, whether the clearances have changed or the water impeller is wearing.

Some plants make a practice of taking test readings of all instruments at regular monthly, weekly, or daily intervals. These readings are always made with as nearly the same load on the unit as it is possible to obtain. If the steam pressures after the control valves and at other stages of the unit show a gradual or sudden increase over similar readings at the same load and vacuum it is a pretty good indication that something is wrong with the turbine blading or nozzles. If the pressure increase is gradual it is probably caused either by deposits on the turbine blading or nozzles, or

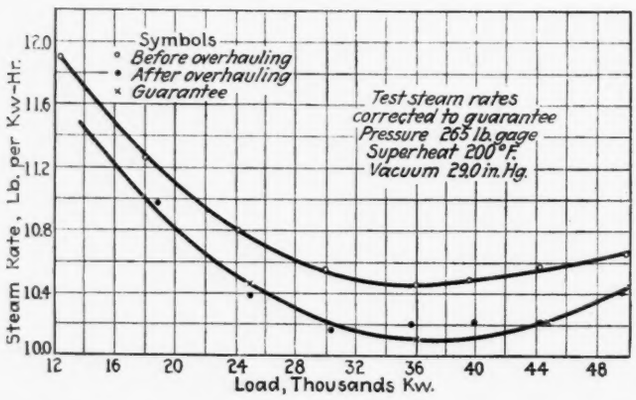


Getting ready to replace the casing after overhaul

by corrosion or erosion. If the increase is sudden, more than likely something has gone through the unit to batter the blades, or a blade failure may have occurred. In either case the cover should be removed and the spindle and cylinder inspected at the first opportunity.

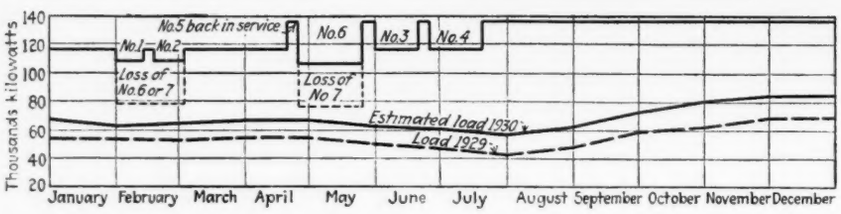
Plants that have poor water frequently experience trouble from deposits in the turbine. Deposits in the high-pressure stages generally have a greater effect on economy and capacity than deposits in the low-pressure stages. In some cases deposits have caused a loss of 15 per cent of a unit's rated capacity. Some success has been achieved in the removal of deposits by passing saturated steam through the turbine, care being taken to reduce the temperature of the steam gradually so as to produce no temperature strains. The effects of this washing with saturated steam may be watched by observing the results of conductivity tests of the condensate, and the operation should be discontinued when normal readings are obtained.

Steam rate tests made at various plants before and after the annual overhaul indicate that improvements of as much as three per cent in economy have been made. The steam rate curves on this page show results of tests on a 50,000-kw. reaction unit. During the overhaul the blades on the high-pressure spindle were regaged and profiled. The first three rows of blades in both intermediate sections were replaced, and stronger lashing wire was used.



Steam rate tests showing the improvement in steam consumption due to an annual overhaul

Reaction turbine opened up for inspection



Overhauling schedule laid out for a plant containing six old and one new unit

In spite of regular maintenance economy gradually decreases below that originally obtainable when the unit was new. This amounts to between 0.2 and 0.8 per cent per year increase in turbine steam rate.

A 10,000-kw. unit bought in 1915 might have had a steam rate of, say, 12 lb. per kilowatt-hour. If this increased at the rate of 0.5 per cent a year the steam rate would now be 12.9 lb. per kilowatt-hour. With a capacity use factor of 63 per cent and steam fuel costs of 30 cents per thousand pounds, the difference between the cost of steam today and when the turbine was new amounts to $15,000 a year. If it be assumed that the turbine could be operated for another ten years, then this added expense during the future life of the unit would amount to a sum whose present worth is $110,000. If a new turbine with a steam rate equal to that of the old unit when new were installed this added cost of steam could be saved. It would be justifiable on this basis to spend not more than $110,000 for a new unit, but a 10,000-kw. unit would probably cost around $160,000. It must, however, be considered that a new unit would probably have a steam rate at least one pound lower than the old turbine had when it was new. Considering the improved efficiency of a modern turbine it would seem that the fifteen-year-old machine has become obsolete.

An investigation of the operating history of 207 turbines made by the Prime Movers Committee of the N.E.L.A. indicates turbines, on the average, are available during 94.56 per cent of the time. Through carefully planned overhauling periods the turbines in many plants have always been available when required to carry the plant load. The table shows an analysis of the cause of outage of the 207 turbines investigated. It will be noted that, aside from outage due to overhauling, blade and nozzle trouble accounts for 18.7 per cent of turbine troubles.

ANALYSIS OF STEAM TURBINE OUTAGE FROM REPORTS ON 207 TURBINE UNITS

	Outage Hours	Per Cent	No. of Units Affected
Steam casing	1,614	1.68	41
Governors	1,025	1.06	69
Control gear	2,947	3.06	74
Shaft packing	5,358	5.57	54
Nozzles and diaphragms	3,340	3.47	19
Shaft	778	.81	11
Wheels	5,322	5.53	31
Buckets or blades	18,010	18.71	41
Vibration	3,011	3.13	25
Bearings	2,543	2.64	55
Lubrication	1,168	1.21	79
Cleaning oil system	2,315	2.40	86
Annual overhaul	45,164	46.93	113
Misc. and unclassified	3,667	3.80	61
Total	96,262		
Per cent outage	5.44		

CONDENSER MAINTENANCE:

Its Influence on

TURBINE PERFORMANCE

Aside from occasional tube renewals, cleaning and stopping leakage of circulating water and air into the steam space sums up the maintenance work that generally has to be done on condensers. It demands the careful attention of the engineer, and its neglect may result in loss of turbine economy and feed-water troubles

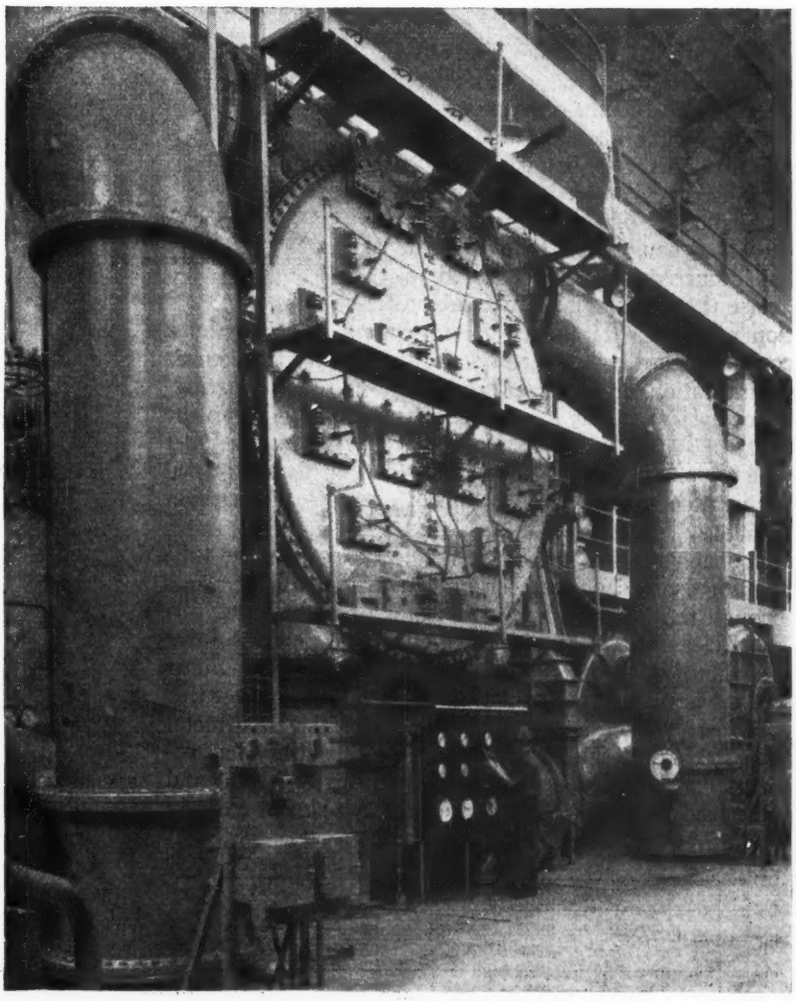


Fig. 1—This condenser installation has been liberally provided with instruments and has resulted in efficient operation

PRACTICALLY all circulating water carries dirt of various kinds into the condenser tubes. This dirt is deposited on the tubes, sometimes forming a slimy coating, sometimes scale of varying hardness. These deposits resist the flow of heat from the steam to the cooling water, and the result is higher steam temperature and decreased vacuum at the turbine exhaust.

Increase in exhaust pressure means an increase in the turbine steam rate. This increase amounts to from 2 to 5 per cent for each half inch of mercury decrease in vacuum, depending upon the load and the turbine design. Increase in steam consumption, in per cent of the consumption at 1 in. mercury vacuum at various loads is shown by Fig. 2. These data are the average of vacuum corrections found by tests on a number of turbines varying in size from 20,000 to 50,000 kw. If deposits were allowed to remain on the tubes of a condenser serving a 10,000-kw. turbine operated on 50 per cent use factor to such an extent that a decrease in vacuum of 0.5 in. resulted, the cost of fuel would be increased by about $5,000 a year. The cost of condenser cleaning is much less than this, so that a net saving can be made.

The frequency of cleaning, of course, depends mostly on the rate of tube fouling. In different plants this varies all the way from four to five times a month to once or twice a year. Some large plants, because of rapid tube fouling, find it necessary to clean condenser tubes every night, working on whatever turbine happens to be available and cleaning as much of the condenser as possible during the night. The remaining portion of the condenser is cleaned during successive nights, if that particular unit is available.

With a given rate of tube fouling the frequency of cleaning should be determined from a consideration of the cost of cleaning, the saving possible due to decrease in vacuum, and the loss due to the outage of the turbine during the cleaning period. The rate of con-

denser fouling can be determined by plotting the circulating-water inlet and outlet temperatures, the condensate temperature, and the temperature corresponding to the vacuum. Each time these data are collected the load on the turbine should be held as nearly the same as possible. As the condenser becomes dirty it will be found that the curves of condensate temperature and steam temperature become further and further apart from the curves of circulating-water temperatures. When the condenser is cleaned these curves come closer together. Fig. 5 represents a log of such temperatures taken during a period of a year on a plant that has particularly good circulating water. The frequency with which these temperature readings should be taken depends largely upon the rate at which the condenser becomes dirty.

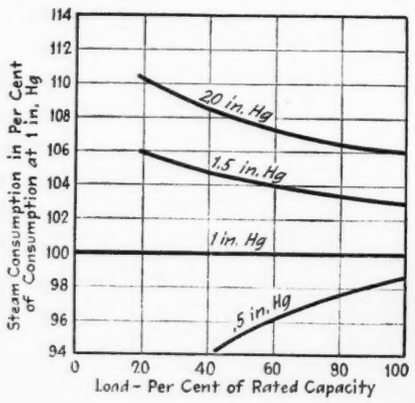
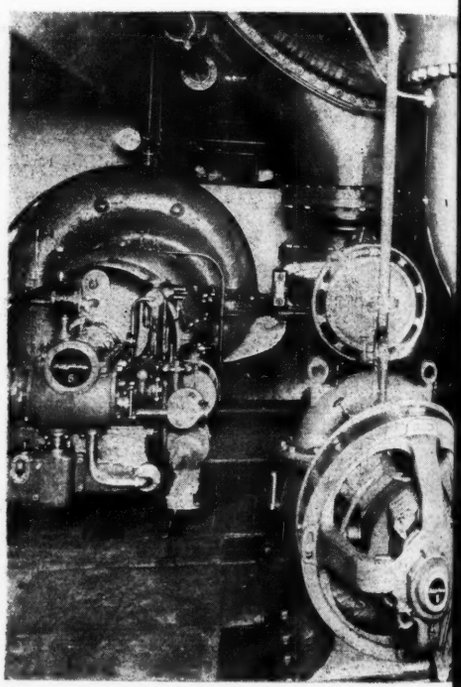


Fig. 2—Curves showing effect of vacuum on turbine steam rate

Such a chart will often give other information regarding condenser operations. If the curves of circulating-water inlet and outlet temperature diverge or converge, it may be taken as an indication that the amount of circulating water used has changed, or that something has occurred in the turbine to increase the steam rate, or a combination of these. If the circulating pump is driven by a constant-speed motor, such a variation may be taken as an indication of increased resistance in the circulating-water system. This may be due to an obstruction in the inlet to the pump, or to material collected on the inlet tube sheet. If the curves of condensate temperature and temperature corresponding to the vacuum do not remain parallel, air leaks should be looked for.

Probably the most popular method of condenser tube cleaning is to shoot rubber or canvas-and-rubber plugs through the tubes, either with water or compressed air. Metal cleaners are frequently used where deposits form a hard scale that the rubber plugs do not remove. Some stations have resorted to the use of sandblasting, but this is rather drastic, as it removes some of the tube metal along with the scale deposits. One large utility has reported considerable success with a mixture of sand and pulverized fuel ash. Addition of the ash almost entirely eliminates the wear on the condenser tubes, though the mixture remains sufficiently abrasive to remove the dirt deposits.

Where the deposit on the tubes is of a slimy nature, due to algae growth, such as occurs when the water is polluted, rubber plugs are not so satisfactory as might be expected. For these conditions some success has been obtained with chlorine in the circulating water. This chemical kills the algae growth and prevents their holding the mud and silt to the tubes. This method has the advantage of eliminating rubber plugging and the necessity of taking the unit out of a service for cleaning. Various other methods of condenser cleaning, such as boiling, or washing with water, and chemicals, are in use. The curves in Fig. 3 indicate the improved heat transfer secured in a condenser through the use of rubber plugs.



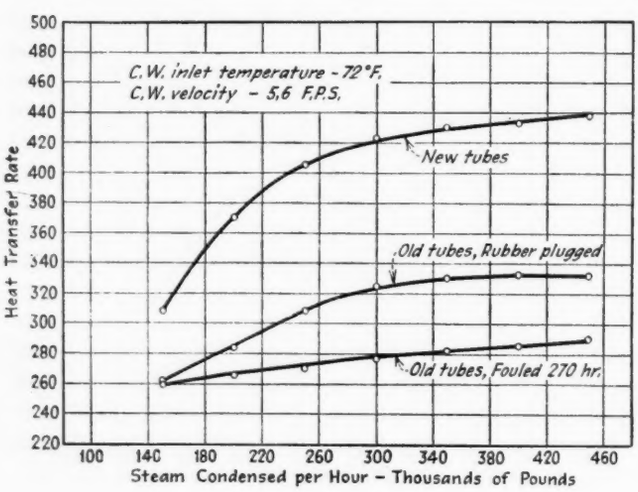


Fig. 3—Effect of condenser cleaning with rubber plugs on heat transfer rate

Many plants have been considerably troubled with condenser tube failures from corrosion and erosion. A condenser tube failure results in the leakage of circulating water into the condenser steam space, and in contamination of the condensate. If this leakage is large, and the circulating water contains large amounts of dissolved or undissolved solids, trouble may be experienced in the boilers. As the possibility of tube failure is always present, a close check of the purity of the condensate should be made daily to determine the extent of circulating-water leakage. In plants using salt circulating water, this check is easily accomplished by making a chemical test for chlorine. For fresh water the check is most easily made by using a conductivity meter and comparing the result with the conductivity obtained from pure condensed steam.

When condenser circulating-water leakage is found, and is due to a tube failure, the tube is generally plugged. This plugging operation is usually continued until about 20 per cent of the tubes have been plugged.

when the condenser is retubed. Circulating water leakage also may occur at the tube packing in the condenser tube sheet. This type of leakage is easily remedied by tightening up the ferrules or renewing the packing.

In high-pressure plants and those designed for high boiler ratings the tendency is to roll the condenser tubes into the tube sheets at both ends. This construction eliminates the chance of leakage at the packing and does not appear to be giving trouble.

Considerable study has been given to the question of tube corrosion and erosion. In some cases it is due to the tubes being of improper material for the particular kind of water used, while in others it has been caused by an electrolytic action. Probably the most prevalent cause of tube deterioration is entrained air and turbulence. Methods of improving this condition are now being studied by a special research committee of the A.S.M.E.

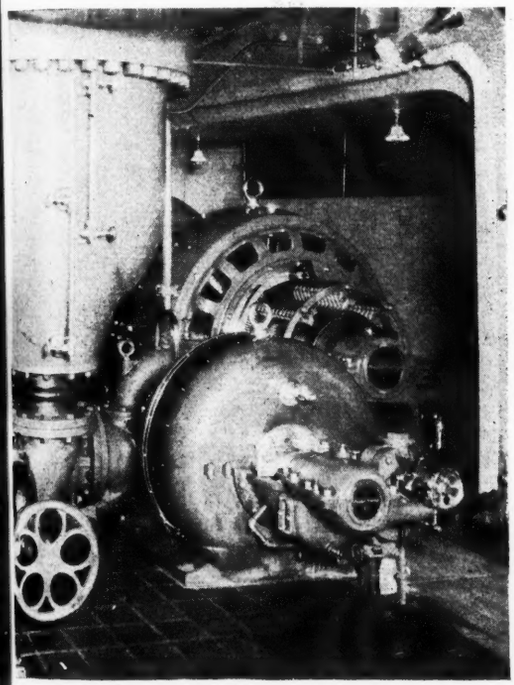


Fig. 4—Condenser auxiliary equipment of an industrial power plant

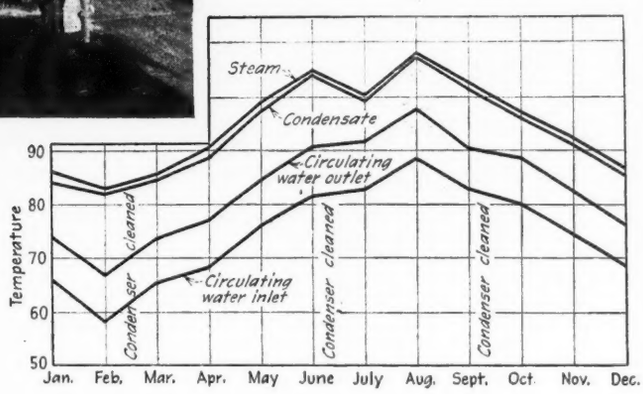


Fig. 5 — Condenser operating data plotted to show effect of tube fouling and cleaning

A large portion of tube corrosion occurs at the tube inlet and extends back about six inches. Some saving in tubes has been secured by using wearing tips. These consist of bell-ended tubes five or six inches long inserted in the condenser tube where the corrosion is going on. The corrosion takes place on these wear tips, and the tube is protected. In some cases the life of the condenser tubes has been doubled.

Excessive air leakage results in more air being present in the condenser, and, consequently, in a higher air pressure. The total pressure in the condenser as indicated by the mercury column is, therefore, also increased, because it is the sum of the air pressure and the vapor pressure corresponding to the steam temperature. Thus with any large amount of air present the condensate temperature must be less than the temperature corresponding to the pressure indicated by the vacuum gage. But even though there is no air leakage in the condenser the condensate temperature would normally be less than the temperature corresponding to the vacuum at the turbine exhaust, because of the pressure drop through the condenser and as a result of sub-cooling due to the condenser design. At a given load the inherent sub-cooling of the condensate would remain the same except as affected by the presence of air in the condenser. Thus, as previously mentioned, air leakage will be indicated by a divergence of the curves of condensate temperature and temperature corresponding to turbine exhaust pressure. This, of course, does not hold true where hot drains are returned to the condenser hot well or when the condenser is arranged with steam lanes for heating the condensate. The effect of air leakage on condensate depression also depends somewhat upon where the air enters the condenser.

Air may come into the condenser through the turbine shaft seal, atmospheric relief valve, or through the various valves and connections to the low-pressure feedwater heaters. It may also come in with the steam, although the amount of air entering in this manner is generally small. Good operation should limit the air leakage to 5 cu.ft. of free air per minute or less. The air leakage should be checked at least twice a year.

Other condensing equipment, such as the circulating pump condensate pump, and air-removal apparatus, will also require some maintenance. It is generally sufficient to inspect this equipment when the yearly overhaul is being made on the turbine. The shaft packing on the circulating pump probably needs to be renewed, as air filtration may otherwise result, which will have a deleterious effect on the condenser tubes. The pump casing should be removed, and the runners and impeller inspected for wear or corrosion. On the condensate pump the same precautions and inspections should be carried out.

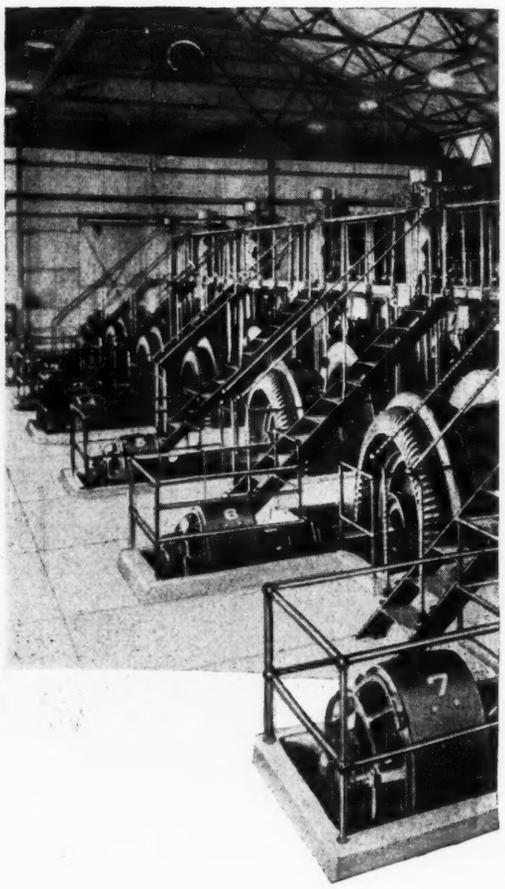
Additional wear sometimes occurs in the condensate pump due to cavitation, particularly if the pump is driven by a constant-speed motor. Cavitation troubles may sometimes be eliminated by providing an adjustable-speed motor drive or automatic regulation at the pump outlet. Sometimes, however, cavitation is due to insufficient water level above the center line of the pump, to too much resistance in the pipe between the condenser hot well and the pump, or to an incorrectly designed impeller. Generally, very little maintenance work has to be done on the air-removal apparatus.

Circulating-water and condensate pumps generally are motor driven. These drives do not require any special attention, the same maintenance and inspection being necessary as indicated in the article in this number on electrical machinery. In some plants, however, the spare pumps are turbine driven and these drives should be inspected during the annual overhaul even though they may have been operated infrequently, because the idle periods offer an excellent opportunity for corrosion, particularly if the turbine stop valve is not tight.

MAINTENANCE

Program of an

Oil Engine Plant



Variation in Diesel plant operating costs, when the costs are computed on identical labor rates and costs of fuel per gallon, are due chiefly to two factors—difference in the load factors and in quality of maintenance

OIL ENGINES long ago passed the experimental stage in their development, and their reliability and economy of operation are accepted as proved by engineers. On the other hand, the cost of maintenance is still a point of dispute, but the relation of maintenance to reliability and economy is seldom stressed.

Examination of recently compiled operating costs of approximately 50 oil engine plants, reveals that there are considerable variations in the total unit operating costs, even when corrected for variations in fuel and labor rates. This may at first glance seem strange, since the fuel consumptions of all makes and sizes is practically identical, but investigation reveals that the accuracy of the data cannot be challenged and that the variations are easily explainable.

Station No._____ Engine No._____ **DIESEL MAINTENANCE LOG** Date:- From _____ To:_____

No. of Hours Actual Running for Interval Specified_____

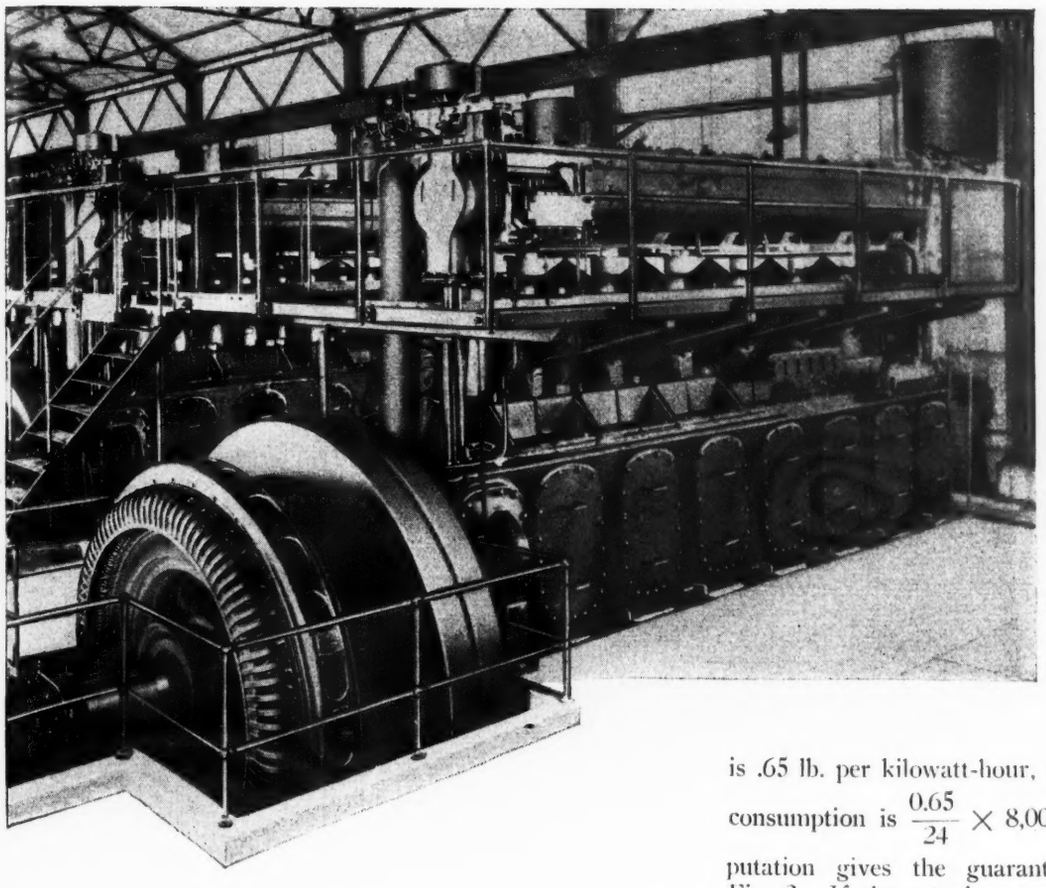
Items to be Inspected	Recommended Max. Hours of Operation	Recommended Max. Elapsed Time Months	Date Work was Done Cyl. No.	1	2	3	4	5	6	Remarks
Piston, taken out and cleaned	6000	12								
Exhaust valves, cleaned and ground	1500	6								
Inlet valves, cleaned and ground	1500	6								
Air starting check valves, cleaned and ground	4000	6								
Air starting valves, cleaned and ground	4000	6								
Fuel pumps, valves cleaned and ground, plunger examined	4000	9								
Spray valves, nut tightness each time engine is shut down	—	—								
Camshaft gears or chains, check and adjust if necessary	4000	—								
Governor, examined and adjusted	8000	—								
Wristpin bearing, checked and adjusted each time piston is removed	—	—								
Crankpin bearing, checked and adjusted	3000	—								
Main bearings, checked and adjusted, alignment checked whenever crankpin bearings are adjusted	8000	—								
Lubricating tanks, lines and passages, cleaned	8000	12								
Lubricating piping, examined for leakage and loose joints	1500	2								
Lubricating oil filter, cleaned, filter bags changed (to be cleaned each shift)	2000	3								
Lubricating oil pump, examined	4000	6								
Cylinder head jackets, examined and cleaned	750	—								
Cylinder jackets, examined and cleaned	4000	—								
Lubricating oil, exchange batches	750	—								
Crankcase, flush out	4000	—								

Fig. 1—A representative maintenance schedule recommended for a medium-sized plant

Variation in operating costs, when the costs are computed on identical labor rates and costs of fuel per gallon, are due chiefly to two factors—difference in load factors and in quality of maintenance. Obviously, the unit labor item increases as the capacity factor, in the ratio of the output to rated capacity, decreases. Lubricating oil costs are adversely influenced by low capacity factor, since the amount of oil used depends upon the wiped surface, and, consequently, upon the rated engine-hours run, and not upon the output.

Despite the uniformity in fuel consumption of all types of engines on the test floors, not always do two units show like results in the field; the discrepancy is due almost entirely to the character of the maintenance, and, surprisingly, the character of the maintenance is in inverse ratio to the cost of maintenance per unit of engine output.

The fuel consumption of a Diesel engine, when considered on the basis of indicated horsepower, decreases as the horsepower drops, that is, its efficiency at low loads is greater than at full load. Frictional losses, however, serve to lower the efficiency per brake horsepower, so that the fuel consumption at three-quarters and at full load is practically constant, with higher values below



A Texas plant containing six 600-hp. Diesels supplying energy to oil-field pump and other commercial loads in the central part of the state

▼

three-quarters load. If the total fuel per hour is plotted against brake horsepower developed, the line is almost straight, as will be seen from Fig. 3, covering a 700-hp. engine.

This fuel consumption, of course, should be followed consistently in every-day performance. In fact, even, if the load varies from one-quarter to full load during the day, the average hourly fuel consumption when plotted against average brake horsepower output should lie very close to the line in Fig. 3. If the operator will obtain from the engine builder a curve of total fuel plotted against brake horsepower, or plot one himself from the guarantee in the purchase contract, he will have a gage by which the every-day performance may be checked; if the daily readings are on the basis of kilowatt-hours, as is usual, the gage curve should be plotted on this basis.

Daily performance, as has been stated, should lie close to the gage curve, and usually is a trifle below, because the builder always has a 3 to 5 per cent margin on his guarantee. In order to detect a gradual falling off in the fuel efficiency, the average hourly load each day should be laid off for periods of a week or a month, as shown in Fig. 2. In addition, the actual daily fuel consumption should be plotted. The next step is to plot the guaranteed fuel consumption. This is easily done by taking the total engine capacity as 100 per cent load and the total kilowatt-hours divided by the total engine capacity as the per cent load to use in finding the guaranteed fuel consumption. For example, the engine has a rating of 500 kw., which for 24 hr. gives a total capacity of 12,000 kw.-hr. The actual output is 8,000 kw.-hr., so the per cent load is $8{,}000 \div 12{,}000 = 66\frac{2}{3}$ per cent. The guaranteed fuel consumption at this per cent load is .65 lb. per kilowatt-hour, so the total guaranteed fuel consumption is $\frac{0.65}{24} \times 8{,}000 = 216.6$ lb. Such computation gives the guarantee performance curve in Fig. 2. If the actual curves and guarantee are similar in shape and fairly close together the engine is functioning satisfactorily. However, when the actual fuel curve shows a sharp departure the engineer should realize that some misadjustment of the fuel injection system has occurred. This may be a bad injection nozzle or an improperly timed fuel pump.

With the gradual wear of the piston rings, the actual fuel consumption curve will reveal a slow drop in efficiency. The engineer must then give some thought to the question of when the pistons should be pulled so that the rings can be cleaned or renewed.

In addition to the fuel consumption record the engineer has a second trouble indicator in the exhaust temperature reading. Any engine should give the same temperature curve so long as combustion is good, but engines of different types do not have identical exhaust temperatures at any stated load.

If the engineer finds that the temperature reading is off the standard curve for his engine by more than, say, 20 deg. F., he can be certain that something is wrong.

With a thermometer or a pyrometer at each cylinder exhaust pipe the behavior of each cylinder can be ascertained. If one cylinder is much cooler than the others, it is safe to presume that it is not getting its share of the fuel, or that the rings are so badly stuck as to let the compression blow by.

As has been stated, the amount and the cost of maintenance of an oil engine are controversial questions. In general, a well-operated plant, running from 3,000 to 5,000 hr. per year, with a capacity factor of not above 85 per cent, should not exceed $4 per horsepower per year for repairs, including running and accident repairs. This is exceeded in poorly run plants, for, paradoxically, the less the maintenance the more the maintenance cost.

The importance of following a regular schedule of inspection and maintenance is, therefore, self-evident.

While different makes of engines and those of different types have characteristics somewhat dissimilar as to the parts that need the closest inspection, still there is a general method of procedure which may, with minor changes, be applied to all engines. A typical maintenance schedule is shown in Fig. 1. Such a schedule system is satisfactory for plants up to, say, 1,000 hp. Engineers of large plants should construct a more elaborate inspection system. This should include individual cards for each engine cylinder, upon which are listed the various parts. This card should be placed in a dated file, a so-called tickler system, so that on the day the exhaust valves are to be inspected, that card is withdrawn and an inspection slip made and handed to the man who has charge of the maintenance. The master card is held in the deferred file, until the inspection slip is returned with notations of what has been done, and the memorandum of new parts, repairs, and extra labor costs should be entered on the back of the card.

Pistons, as the schedule shows, should be taken out and cleaned after 6,000 hr. of service, and, in all events, once a year. This is based on the use of a good grade of fuel oil. If, for economy, a cheaper and less desirable grade is used, the inspection may need to be done more often. Otherwise, a tarry substance will settle out of the fuel and gum the pistons so they are immovable in their slots. This sticking will result in gas blowing by the rings into the crankcase and in loss of power.

If a certain oil is found to gum up the rings excessively, it is well to consider the advantages that might result from a change in oil.

It should not be assumed that all piston troubles are eliminated by scheduled inspection. Due to excessive loads, poor design, or faulty cooling, fractures may take place in the piston crown. These will make themselves known through the blowing of the gas into the crankcase. At the scheduled inspection the piston crown should be examined for incipient cracks.

Exhaust valves require inspection after about 1,500 running hours. With a good fuel, assuming the fuel spray valve to be properly adjusted, the exhaust valves should still have a good seal even after six months' operation. But a dirty, gritty oil, or one having a salt content, may cause valve leaks in less than a month. Other grit and dirt can be eliminated by proper centrifuging.

For this reason proper maintenance methods include the use of a fuel-oil centrifuge, even though the refinery has given the oil a filtering treatment before shipment.

The fuel pump of air-injection Diesels is under a comparatively low pressure, of about 1,000 lb. per square inch. It is therefore not seriously affected by leakage, although a leaky suction or discharge valve will cause the particular cylinder it feeds, to either cut out entirely or receive so little fuel as to overload the other cylinder.

The high-pressure airless, or pump, injection engine has a fuel pump pressure ranging up to 6,000 lb. A leaky pump valve rapidly cuts out, and maintenance of the pump parts is of serious moment.

Slow-speed, two-cycle engines will operate with a badly worn crankpin bearing without the engineer's knowledge, for the upper half of the crankpin bearing is always in contact with the pin. But when speeds are increased, the added inertia force may be great enough to cause this part of the bearing to leave the pin, which will then contact with the opposite bearing half, producing a pound.

A four-cycle engine, if slack in the rod bearing, may pound on the exhaust and suction strokes. It is necessary to maintain close clearance, but as the pound indicates a bearing needing attention, a four-cycle engine is easier to adjust properly than is a two-cycle, which may wear out all the bearing babbitt without giving an indication of trouble.

An increase in the clearance between the shaft and bearing cap is indicative of wear in the lower half of the bearing. If this wear is enough to permit the shaft to materially deflect when the adjacent cylinder fires, eventually the shaft will break. Consequently, a check of the clearance between the top cap and the shaft, or the clearance between the shaft and the bridge gage, supplied by the engine builder, will reveal wear of the lower bearing. It must be remembered that if the shaft is checked with the pistons and rods removed, it may not have enough weight to cause the two to settle in the low bearing, consequently deflection may not occur.

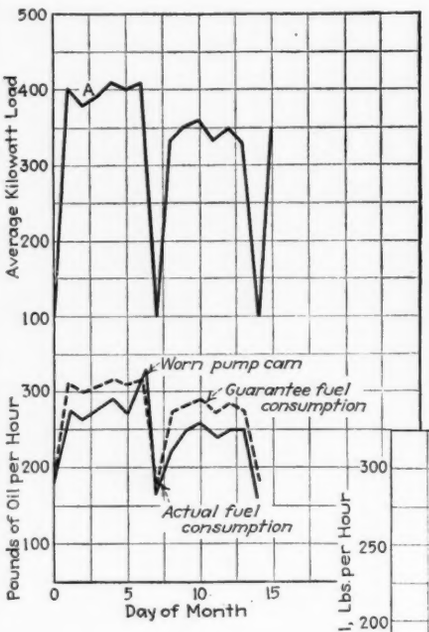


Fig. 2—Plot of load and fuel consumption

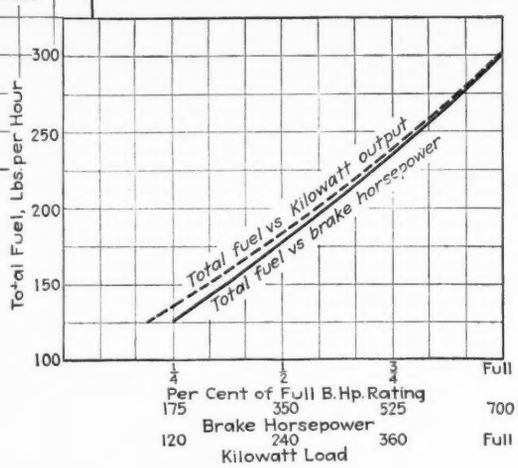


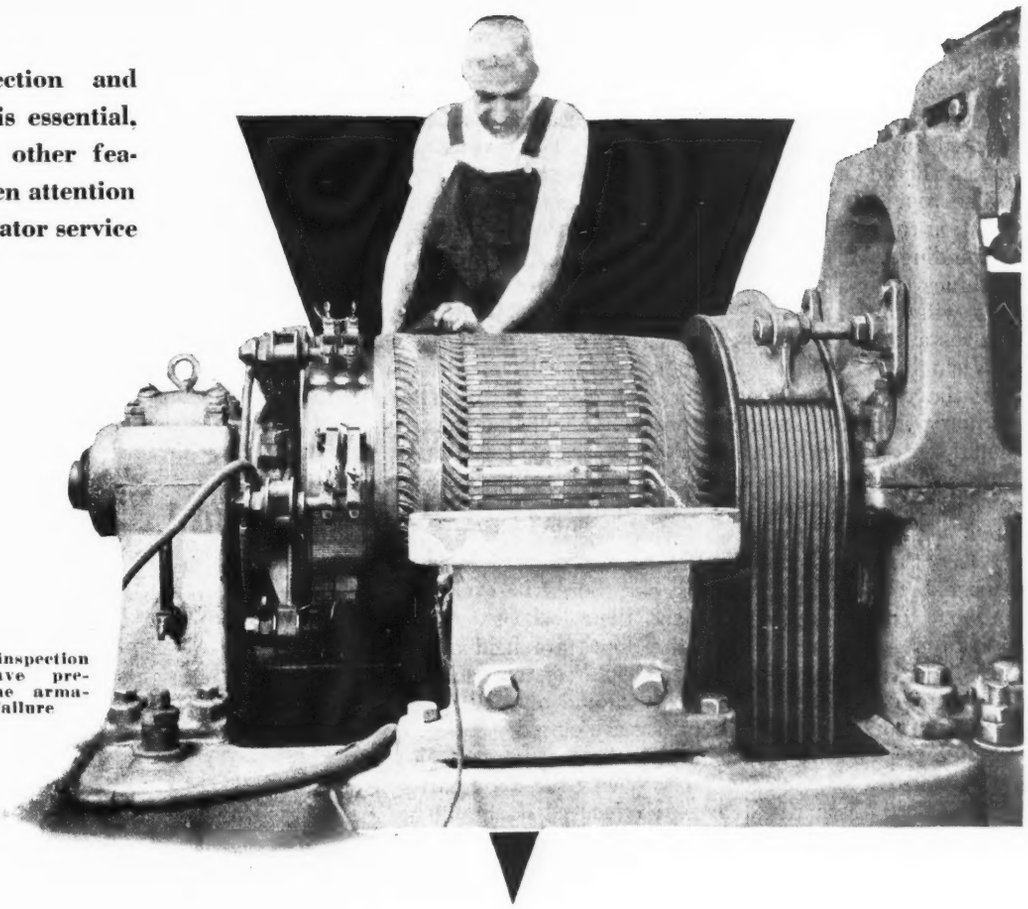
Fig. 3 — Fuel consumption on a brake - horsepower and on a kilowatt-hour basis.

Fuel nozzles and spray valves are delicate parts, and grit rapidly destroys their usefulness. To insure reliability of operation, these parts should be closely examined, and a magnifying glass used to examine the interior seats.

Much of the trouble experienced in oil-engine plants has been due to inferior auxiliaries. For example, hundreds of oil engines are being operated with but mediocre lubricating-oil treating methods.

Other adjuncts of a Diesel plant that reduce maintenance are low-water alarms in the cooling system, safety stop in the lubricating oil line, temperature alarm in the jacket water, and electrical heaters in the fuel-oil line.

An adequate inspection and maintenance system is essential, but there are many other features that must be given attention for good low-cost elevator service



Proper inspection could have prevented the armature failure

Making ELEVATORS *Give* SERVICE

INSPECTION and maintenance of elevator equipment is closely associated with the operation of the machines. To render satisfactory service the equipment must be kept in good working condition. The safety of the passengers and those who may be at the landings depends upon the condition of the equipment. An elevator in bad repair may fall to the bottom of the hoistway, or be pulled into the overhead work and cause a serious accident.

A regular system of inspection is one of the essentials to rendering good elevator service and keeping the equipment in a safe operating condition. Where to begin inspecting elevator equipment is a question that engineers are not agreed upon. Where some will start with the motor, others will begin with the hoistway doors, or start on hoisting ropes. It makes little difference where the work is started so long as it is thorough.

Starting at the motor, the lubrication, the condition of the bearings, the brushes and commutator, and any evidence of winding trouble are noted. On worm-gear machines the position of the armature or rotor between the bearings should be checked. When the thrust bearings wear they may allow the thrust of the worm shaft to be transferred to the motor bearings. The latter are not designed to take the thrust, and they may overheat if subjected to it.

Next to the motor comes the brake. On its adjustment and condition depends, to a degree, the safety of the passengers in the car. If it is not working properly the operator will make many false stops. These not only impair the elevator service, but also increase the power consumption per car-mile. Therefore, safety, service, and economy dictate that the brake should be properly adjusted.

The control equipment may be given third place on the program. All contacts should be examined to ascertain that they are functioning properly. There are many things that can happen on a controller, such as contacts out of adjustment, shunts loose or broken, and contacts and other parts loose or broken, all of which should be located and repaired before they cause trouble.

While in the motor room the elevator machine should be checked. If the machine is of the gear type, check is made of the height of the oil in the gear case. Its level should be at the center line of the worm. The worm should not have excessive thrust. Before this condition exists the thrust bearings ought to be adjusted or renewed. Lost motion on the drum is usually due to one

or more of four causes: worn thrust bearings, worn gear teeth, loose or worn bearings, and the gear loose on the spider. All the causes should be checked and corrected if found to exist. The only remedy for a badly worn gear is to replace it. The drum and sheaves should be checked for looseness on their shafts. Their rims and spokes should be examined and hammer-tested for cracks.

The ropes on the drum and sheaves should be given attention to see that they lead off and on the drum without binding. Where deflecting sheaves are used on drum machines they should move freely on their shafts, or they will cause the ropes to rub on the side of the grooves and result in unnecessary wear.

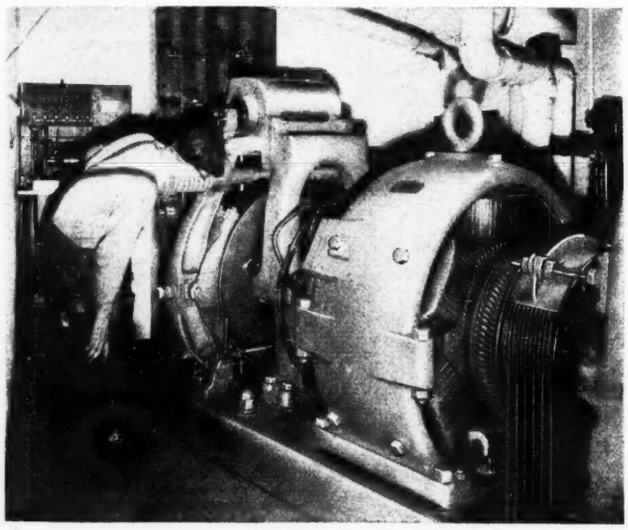
When inspecting the governor, the flyballs are lifted until the rope-gripping jaws are released, noting if the auxiliary switch functions properly. The governor should be reset, care being taken to see that the auxiliary switches are also in their correct position. The governor should be kept clean and all moving parts lubricated.

After the equipment in the motor room has been inspected, the hoistway and the car should be given attention. The hoistway doors and their locks should be carefully gone over. Where the doors are held closed by ordinary latches, the inspector should try to open each door without lifting its latch. It should also be noted if the doors latch readily when they are closed.

When the doors have interlocks, the inspector should try to start the car at each landing with the door partly open. If an automatic door closer is used it should be noted how far the doors are open when the interlock closes and the car can be started. If the doors are power operated, all parts of the operating mechanism must be examined carefully to see that it is in proper working order.

The safeties under the car should be examined by the inspector getting down into the pit and having the operator lower the car to expose all parts. The guide shoes should be replaced before they are worn sufficiently to allow the safety shoes to come in contact with the rails. The safeties should be operated by hand to insure that they are in good working condition, and all moving parts must be kept well lubricated. While the inspector is in the pit he should examine the oil buffers to see that they contain sufficient oil.

When the car has compensating ropes, they should be examined from the pit. The best way to do this is first to examine the connections at the car to see that they are secure and that there are no broken wires at the sockets. Then while the operator raises the car about three feet at a time the inspector examines the ropes for broken wires or other objectionable conditions. When the car has reached the top of the hoistway, if the counterweights come down far enough, the ropes' connections to their bottom can be examined, as can the lower guide shoes. If this inspection cannot be made from here, it can be taken care of from the top of the car. The length of the ropes should be noted. With the car at the top landing there should be one or two feet clearance before the counterweights will land on the buffer in the pit. The position of the governor-rope and the compensating-ropes sheaves should be noted, to see that they are



The brake should be kept in good adjustment

ELEVATOR RECORD
HIGH RISE
THE EQUITABLE LIFE ASSURANCE SOCIETY'S BUILDING
393 SEVENTH AVENUE, NEW YORK, N. Y.

DATE _____ 19__

ELEVATOR SERVICE	ELEVATOR NO.	TRAVEL	STOPS	HOURS IN SERVICE	CAR MILES METER READINGS START	CAR MILES METER READINGS STOP	MILES PER CAR	KILOWATT HOURS METER READINGS START	KILOWATT HOURS METER READINGS STOP	K. W. H. PER CAR	K. W. H. PER CAR MI.	TRIPS PER CAR	CAR STOPS TOTAL	CAR STOPS PER MILE	CAR STOPS PER TRIP
PASS'R	1	368'–4"	2SB. TO 22												
	2	368'–4"	2SB. TO 22												
	3	368'–4"	2SB. TO 22												
						TOTAL									
						AVERAGE									

CONDITION OF CABLES:

			VARIABLE VOLTAGE TYPE	RHEOSTATIC TYPE	
TOTAL	K. W. H.				
	MILES:	AVERAGE K. W. PER CAR MILE			
	TRIPS:	AVERAGE MILES PER CAR			

SIGNED:

CHIEF ENGINEER

Daily records of elevator operation provide a check on both the machines performance and on the operator

in a position to function properly and have sufficient clearance under them.

The hoisting ropes and governor ropes can be best inspected from the top of the car. With the inspector on top, the operator runs the car to a position in the hoistway where the counterweights can be reached. These can be inspected first, and then as the operator raises the car, about two feet at a time, the inspector should carefully examine the ropes. The car guide shoes, limit switches, and other equipment that may be on top of the car and in the hoistway should be examined as part of the ropes-inspecting job. In the car the chief objects of attention are the car switch and the gate. The safety switch should be opened and the car switch moved to the on position to see if the potential switch drops out and cuts the power off the motor, as it should. The cover is next removed from the car switch and the contacts inspected to see if they are in good condition and functioning correctly. If the gate has a contact to prevent the car's being started with it open, that should also be checked. If the car starts with the gate open, a search should be made for the cause of the short circuit on the contact circuit.

The equipment to be inspected and the method of doing it will vary with the type of machine, but the foregoing suggests a system that covers the most important features of any installation. In the maintenance of elevators, like with any other equipment, keeping it clean is about 75 per cent of the job. If equipment is thoroughly cleaned every week or two, most of the little defects will be detected.

The largest item of maintenance cost of a modern high-speed elevator is the ropes. Operating conditions have a marked influence on rope life. Some of these are controllable, others are not. In a given installation unequal loading is probably one of the chief causes of short rope life. On a traction machine this may develop from unequal stretch of the rope or unequal tread diameters, or the grooves in the traction sheave will cause one rope to travel faster than the other, producing slippage and unequal loading.

Much of the difficulty with slippage can be overcome by putting the grooves in good condition before the ropes are installed. However, this cannot prevent unequal stretch of the ropes or take care of unequal wear of the grooves during the life of the ropes. To automatically compensate for these faults it is general practice to install equalizers on the hoisting ropes, and in some installations these are also put on the compensating ropes.

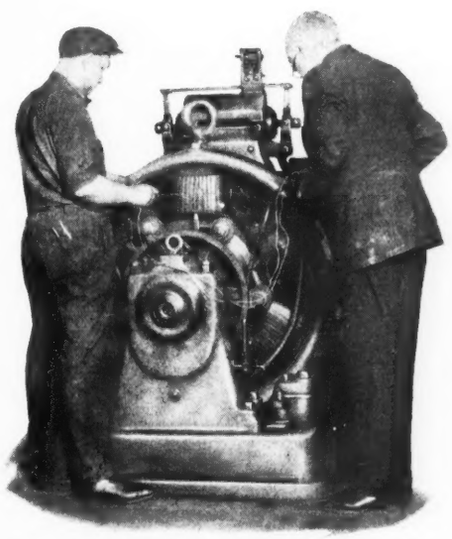
Devices such as commutator stones and grinders, commutator undercutting tools and hand motor-driven blowers have a place in the maintenance of the electric equipment on elevators just as they have on electric machinery for industrial purposes. Once each year, or every two years, depending on conditions, the motor windings should be given a thorough cleaning and a coat of air-drying insulation varnish.

Lubricating the guide rails by hand has always been not only an unpleasant job, but also an unsatisfactory way of doing the work. When they are first greased there is too much lubricant on them, and before they are greased again they are frequently dry. Several automatic guide-rail lubricators have been developed that reduce the job to filling a reservoir with oil or grease every month or at longer intervals. These devices relieve the maintenance men of a dirty and dangerous job, insure the rails' getting a continuous supply of lubricant, and the car does not have to be taken out of service to grease the rails.

Metering devices are valuable tools in a proper operating and maintenance program. A megohm meter should be used to check the electrical machinery's insulation. A watt-hour meter on each elevator in connection with a mileage recorder are used to obtain a record of power consumption per car-mile. They show the daily mileage of each car and the rope life. When stop counters are used on car-switch controlled elevators, their record combined with those of the mileage recorders will provide a means of obtaining the stops per car-mile and per trip. This is valuable in checking up on the operators and the brake adjustment. If an operator is making an excessive number of stops it shows that many of them are false, either through the fault of the operator or because of an improperly adjusted brake. A study of records of the number of stops per car-mile and of power consumption shows that power per car-mile invariably increases as the number of stops increase. The accompanying record sheet shows the daily report used in a well-operated office building. Not only is the power consumption low, but the maintenance charges are extremely low.

Modern elevator equipment has been brought to such a high degree of development that its expected life can be assumed to be that of the building. However, there are many conditions in the older types of buildings where changes can be made that will improve elevator service. Even modern elevators may be made more efficient and the service improved by changes in the auxiliary equipment. The old signal system may be replaced by one that is more effective; an automatic scheduling system may be installed to dispatch the cars instead of having this done by the starter; manually operated doors may be equipped with automatic closers or they may be power-operated and an improvement in the service obtained.

In the older types of buildings many changes may be made, even to installing complete new elevator equipment. Frequently, old controllers are replaced. Where the machines are operated from alternating current it is often possible to replace the old motor by a new one and reduce the power consumption by one-half, improve the elevator service, and reduce the maintenance cost, thereby effecting considerable saving.

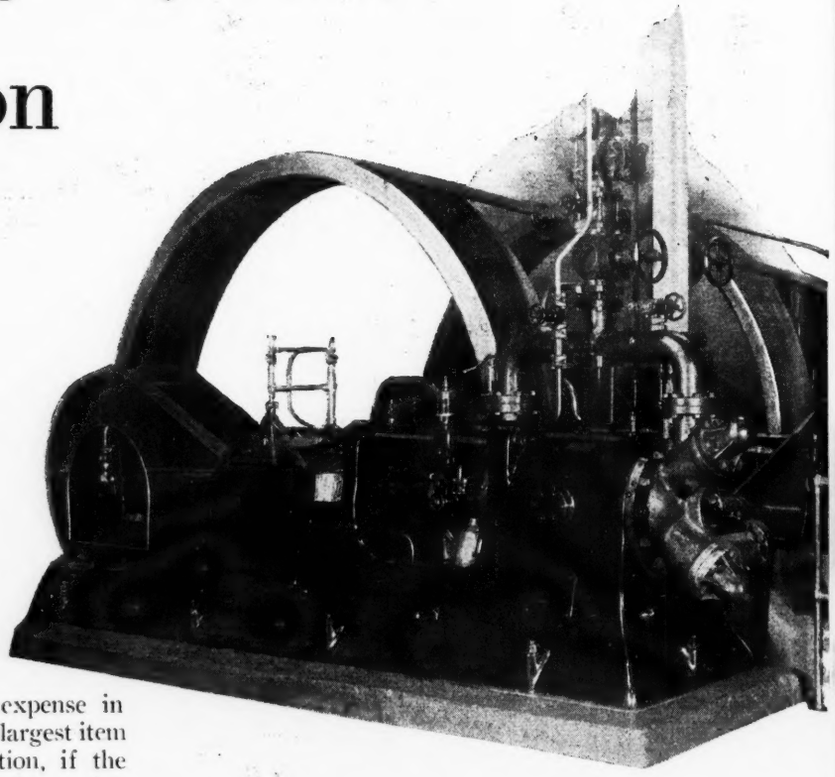


Inspecting insulation with a megohm meter

Seasonal

Overhauling Pays *in the* Refrigeration Plant

The properly maintained refrigerating plant is not the one being shut down as a result of high operating costs



UNLIKE many industries, the power expense in an ice plant or cold-storage plant is the largest item in the total cost per ton of refrigeration, if the overhead charges be ignored. Consequently the equipment must be kept in excellent operating condition, which entails a continuous maintenance program. A second factor influences the degree and character of the upkeep, this is, freedom from service interruptions.

The cold-storage plant is quite similar to the electric utility, in that it must be prepared to give continuous service to its patrons, and beyond this it is responsible for any damage to stored goods occasioned by service interruptions. The ice-making plant must, if its full profit is to be obtained, be prepared to deliver ice when and as demanded by its patrons. In any case neglect of small defects may speedily result in property damage entirely, proportional to the importance of the initial defect. In other words, running repairs must be made instantly upon the advent of a defect.

There are, however, many defects that while increasing the cost of operation cannot be corrected by work done during an hour's shutdown, and as refrigerating plant operation is on the basis of 24 hr. for the seven days a week, these adjustments must be delayed until there is an opportunity to shut down for a week or a month for a complete overhauling.

It is with the overhaul period that this article is concerned.

As a basis for this work, to be done during the winter overhaul period, the engineer should record in a log book the various defects as they occur, so that he may be able to lay out a comprehensive plan of overhaul. In spite of this log hidden defects may exist, so the wise engineer takes nothing for granted.

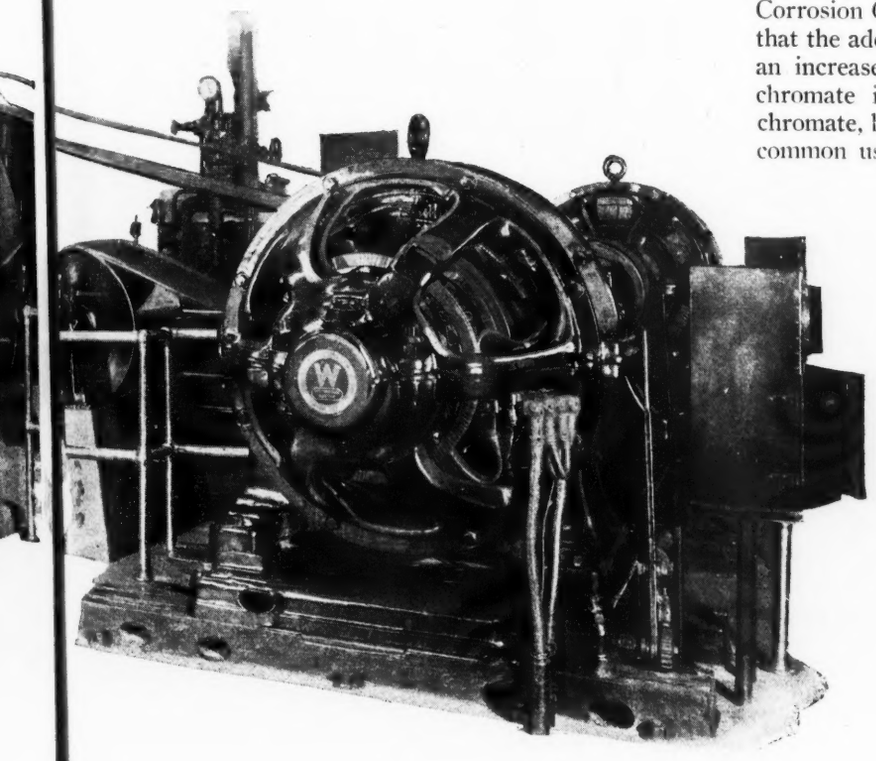
In the days of slow-speed compressors, scored cylinders and worn piston rings were of infrequent occurrence, but the higher-speed present-day machines are by no means immune to this trouble. The cylinder head should be removed to permit examination of the cylinder walls and for calipering of the diameter for wear. Removal of the piston and rod, which is not difficult, is the only way by which the condition of the piston rings can be noted.

Valves should be removed and cleaned, and if found cut should be reground or replaced. Usually light disk valves are hard to reface, so new ones are to be preferred. Much of the trouble with slow-speed compressors is due to poor design of poppet valves, and in many cases the replacement of these heavy pairs by light disk or wafer valves will increase a machine's capacity and reduce the power per unit of output.

Stuffing-boxes should be repacked during the overhaul period if fibrous rings are used, even though such rings have records of two or three years. If stuffing-box leakage is a constant occurrence, it might be desirable to use some one of the several

metallic packings on the market. While slow-speed machines generally have a large connecting-rod-to-crank ratio, which eliminates serious crosshead guide thrust, many modern high-speed machines employ a small ratio, so that the crosshead shoe wear may be severe and cause leaky stuffing boxes. Alignment of the rod should be rechecked and the crosshead shoe adjusted to bring the rod central in the stuffing box.

Likewise, the rod bearings should be checked for wear. It must be remembered that the higher speeds of today place greater unit stresses on the bearing, and wear should not be expected to be as minute as on a 90-r.p.m. compressor. The shaft should be adjusted to its original position, especially if the driving motor is on the machine shaft. Maintenance of uniformity in the air gap between rotor and stator is essential. The stop valves on the suction and discharge lines are entitled to examination, and, if necessary, the seats should be replaced or reground. The relief valve, if it has opened at all during operation, may be prone to leakage; this should be checked.



Of prime importance is the condition of the condenser tubes. Where the cooling water contains algae, the moss-like growth on the tubes may have seriously affected the condenser's performance. The tubes should be thoroughly de-mossed and freed from all scale or sediment, after which a coating of hot asphaltum or one of the several pipe paints available should be applied.

While the interior of the pipes ordinarily is clean, excess lubricating oil may have deposited there. It is worth while to remove the end return bends or other connections so that any such deposit can be removed. If the plant is a new one, pipe scale will undoubtedly be found within the coils.

Expansion valves should not leak, but, unfortunately, leaks are of common occurrence. This prevents the complete isolation of a coil, and regrinding of those valves is justified. At all events inspection should be made. In those modern plants that use liquid-level controls, the float box may be more or less filled with oil and pipe scale, so the control valve should be tested for leaks and for pin holes, which might later cause collapse of the ball. The control valve seat and mechanism should be examined for signs of wear.

In the past the greater trouble occurring in an ice plant was corrosion of the ammonia coils and of the ice cans. Of late, treatment of the brine has eliminated much of this trouble. It is necessary to maintain the non-corrosiveness of the brine, which is best done with sodium dichromate.

The influence of sodium chromate on the corrosion of iron and steel by calcium brine was investigated by the Corrosion Committee of the A.S.R.E. It has been found that the addition of sodium dichromate to the brine gives an increased protection to iron and steel when the dichromate is neutralized, that is, converted to sodium chromate, by the addition of caustic soda. Because of its common use, however, dichromate is cheaper and more readily available than chromate. It is therefore advisable to purchase the dichromate and neutralize it in the brine tank.

If 74 per cent commercial flake caustic soda is used for neutralization, 35 lb. should be added for each 1,000 lb. of dichromate. Slightly less than this amount of caustic is necessary if the brine is alkaline before treatment.

Tests on galvanized material, brass, bronze, and Admiralty metal showed that about 90 per cent protection to these metals can be obtained by the use of dichromate neutralized with caustic soda.

It is, of course, necessary to know when the proper amount of chemical has been added, for the alkalinity must be held to almost the neutral point. The only safe method to follow is to use a suitable testing apparatus, which is procurable at low prices from several manufacturers. The element of guesswork should be eliminated when corrosion is being studied.

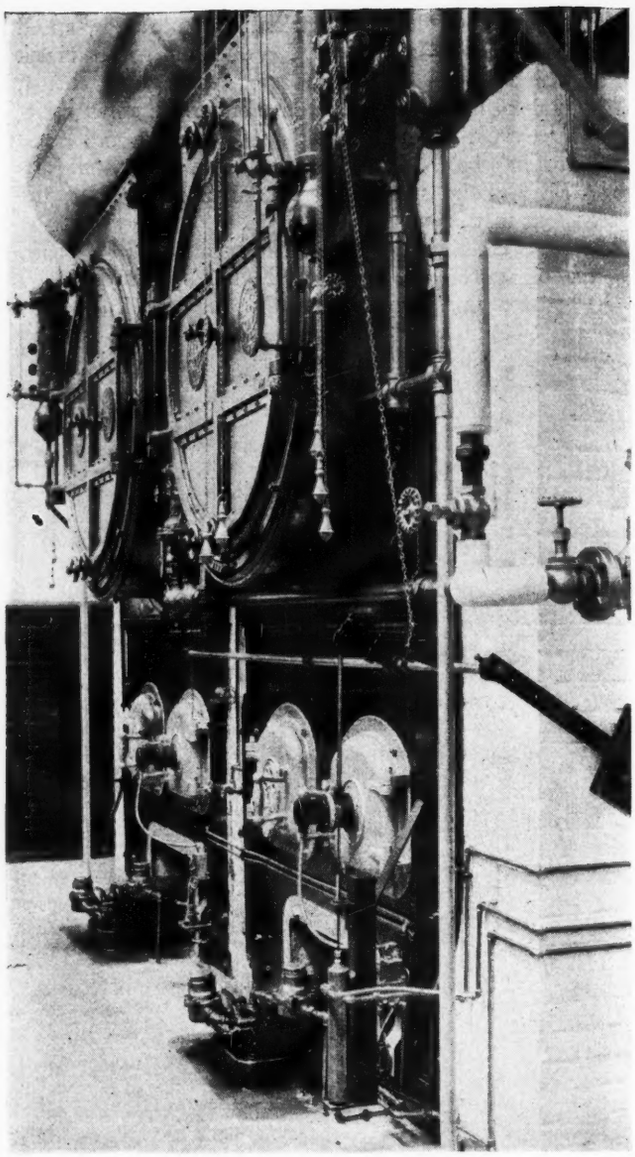
Ice cans are entitled to inspection and repair. If the tin surface is gone or partly destroyed the cans can be re-tinned. The agitation-air lines should be blown clear with steam and the rubber nipples renewed. The air receivers must be cleaned of the accumulation of oil and dirt carried over from the compressor.

Where a plant is fortunate enough to possess two brine tanks it is well to empty one at a time, so that the seams of the steel plate can be examined for leaks. Welding will repair any joint or pin-hole leak, and if a plate is found corroded badly a new plate may be seam welded over the defect.

Advances in refrigerating engineering practice have been so marked during the last ten years that the engineer does well to study the advantages of replacing part of his old equipment with new.

The cooling towers of plants built fifteen or twenty years ago are usually very inferior in performance. Their inability to cool the water to within a reasonable distance of the wet-bulb temperature forces the pumping of too much condensing water. Newer designs are more efficient, and therefore reduce the cost of water pumping.

Care of Heating and Ventilating Systems



HEATING system upkeep differs from power plant maintenance in that a large part of the work is deferred until the summer, when the equipment is idle. It is further influenced by the necessity of preparing equipment so that it will not deteriorate while not being used.

Although most of the maintenance work is done during the summer, there nevertheless is some work that has to be done while equipment is in operation. Leaks in piping and around valve packing cannot be put off, but must be attended to immediately, even though repairs may be of a temporary character. Ventilating equipment generally operates the year around and maintenance on it is done when required. Most of the upkeep during the winter is of an emergency nature. As much as possible of it is done at night or on Saturday afternoon and Sunday, when heating requirements are curtailed.

That much of the repair work is deferred makes it important that a record be kept of all work to be done during the overhauling period. Trusting to memory for this will result in a last-minute rush when the heating system is started in the fall and consequent slipshod work, or else the troubles of the previous season will be lived over again.

It is well to keep a separate book or file for each piece of main equipment, such as boilers, fuel-burning equipment, vacuum pumps, heaters, traps, and piping, in which troubles experienced during the heating season and repairs to be made are recorded. Such a log is a real convenience during the maintenance period.

Since practically all of the overhauling is to be done during the summer, it is not well to procrastinate. Maintenance should be started as soon as the heating season is definitely over and the system shut down. By keeping on the job the overhauling can generally be accomplished by the regular operating crew before the next heating season sets in. Furthermore, if it is discovered that new parts are required, an early start provides time for such equipment to be obtained before cold weather arrives.

The boilers make a good place to begin, and the first job is that of cleaning them, both on the water and fire sides. Unless the feed water is particularly bad, little scale collects on the water side, since the boiler uses it over and over again. But rust and dirt from the radiators and piping are carried into the boiler, and this should be cleaned out.

Soot deposit on the fire side of the boiler surface decreases boiler efficiency in the same way as dirt on the water side. Best operation demands that it be regularly cleaned off during the heating season, but all too frequently soot blowers are not installed and the soot is allowed to accumulate. That general practice makes the spring cleaning all the more important. Soot collecting at the base of the stack and in the flues should also be cleaned out, for if allowed to remain it may result in corrosion. Also the moisture that it will absorb during the summer will cause it to cake, and further accumulation decreases the available draft, and, therefore, the boiler's capacity.

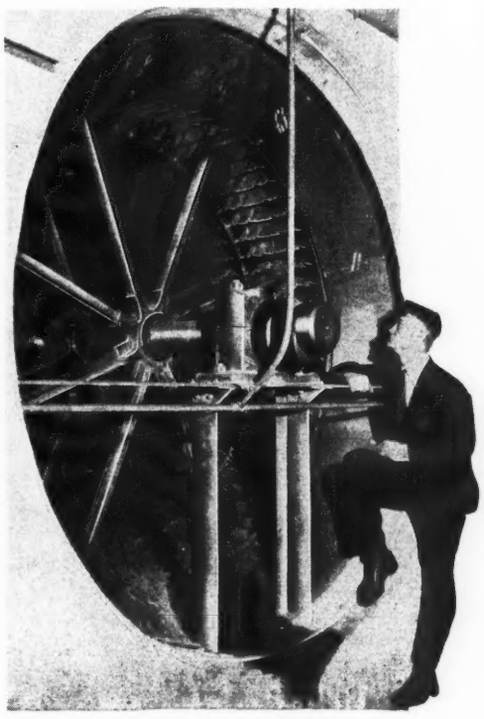
With the boiler clean, it should be thoroughly inspected for cracks or leaks, and repairs made as indicated on the logs or as found necessary by inspection.

Maintenance work necessary on the furnace and fuel-burning equipment depends upon the type installed and the way in which it is operated. If the boiler is hand-fired little more than cleaning is normally necessary, but if grates are cracked or warped they should be replaced. If stokers are installed the maintenance work may be more extensive. That detail is covered in another article in this number.

It is generally considered good practice to coat the drum with graphite or other protective material and to fill the boiler with water before leaving it for the summer; air is thus excluded, which tends to decrease the amount of corrosion. The boiler dampers should be closed and some slaked lime put in the furnace to absorb moisture and so decrease the amount of rusting.

With the work on the boilers completed attention can next be turned to the pumps. Vacuum pump receivers and strainer should be cleaned. If the pump is driven by electric motor it may be that the float control needs attention. Centrifugal pumps should be opened up and runners inspected for wear or corrosion. It is generally best not to replace shaft packing until just before the pump is to be replaced in service. Packing tends to dry out and become hard during the summer, and efforts to stop shaft leakage by tightening the gland may easily result in a scored shaft. On steam-driven reciprocating pumps maintenance work may be extensive, depending on the pumps' age. Valves will probably need cleaning and scraping, and their setting checked. It is good practice to replace all piston-rod packing. Piston rings and cylinders should be inspected. If a pump is old the rings may have to be renewed and the cylinder rebored or liners renewed. When maintenance on an old pump becomes as extensive as this it may prove more economical to purchase a new one of modern design and improved operating efficiency.

It will be found good economy to go over all radiator traps, even though they may not have caused any trouble. Pitted seats and disks should be reground and the working parts dipped in oil to prevent rusting while they are standing idle. One engineer reports a 75 per cent reduction in trap replacement by following that procedure. If the traps are of old design it is good policy to replace them with a modern type, instead of spending time in repair work. A number of manufacturers have designed the working parts of their newer traps so that they can be installed in the old trap body with but little work and without disconnecting the trap body from the radiator. The maintenance routine ought also include those traps used to return drips from risers and steam headers to the main radiator return line, boiler return traps, and air vents.



When steam for heating is obtained from a high-pressure line the reducing valves used to drop the pressure to that required for heating should be thoroughly gone over. Seats and disks will probably need to be reground, valve stem packing renewed, and the diaphragm inspected for cracks and wear. Reducing valves are the heart of such systems, and for that reason great care should be taken to see that the operating mechanism is left in good working condition.

Dirt pockets are generally provided at the heel of all risers. If new they will probably need cleaning, but on older systems they do not have to be cleaned every year.

If, during the heating season, a temporary repair was made on a leaky steam pipe or return main, the temporary work should be removed and a permanent repair made. This may require a new piece of pipe and fittings or merely a new gasket. If the leak was in a threaded joint and the pipe is otherwise in good condition welding may be an economical and permanent repair.

In some localities considerable trouble may be experienced from corrosion, mainly with certain types of feed water and feed-water treatment. It depends largely upon the composition and quantity of non-condensible gases evolved with the steam, of which oxygen and carbon dioxide exert the greatest influence. When about 4 per cent of carbon dioxide is mixed with the air in a heating system the rate of corrosion is approximately doubled.

A common source of carbon dioxide in steam heating systems is from the bicarbonate hardness of the boiler make-up water. It may also be generated by the decomposition of soda ash, which is commonly added to the feed water to prevent the formation of hard scale. Thus any means taken to decrease the amount of make-up will tend to decrease corrosion.

An effective method of cutting down the rate of corrosion in return lines, due to the presence of air and carbon dioxide mixtures, consists in providing a complete gravity flow of condensate from all portions of the system, thus eliminating dead ends. Adequate vacuum pump capacity keeps the carbon dioxide content of the gases low by reason of the sweep-out that results from unavoidable inleak of air. It is far wiser to endeavor to prevent corrosion than to attempt to keep in repair a system in which corrosion is allowed to continue unchecked.

Ventilating and air conditioning systems usually operate both winter and summer. There is no idle period, as in the heating system, when a general overhaul can be undertaken. Repair work must be done whenever the opportunity arises, such as at night or over week-ends.

Fan maintenance consists mostly of bearing repair, cleaning dirt from fan blades, and electrical work on motor drive and control, which is covered in another article in this issue. Where direct drive is used the flexible coupling will need regular attention.

Keeping

ELECTRICAL MACHINERY

on the JOB

THE INSPECTION and maintenance problem is always with the power engineer. It begins with the installation of the equipment and does not end until the machine goes to the junk heap. Operating conditions have an important influence on the cost of maintenance, but the intelligence put into selecting the equipment is a greater factor. If the motor and control are not suited to the application, maintenance costs will be high and production, and probably the quality of the product, will be below normal.

When selecting equipment, attention should be given to the ease with which parts can be inspected and replaced. On a controller the parts should not only be substantial and function according to sound principles, but they should be readily accessible. In motors a large armature shaft is desirable. Where sleeve bearings are used, if one happens to run dry, on a shaft of substantial size, the increased load on the motor will probably open the protective device before destroying the bearing. This leaves the motor ready for service when the bearings have been lubricated. In some cases it may be necessary to scrape the bearing, but this will generally take much less time than to make a replacement, particularly if the spare part is not readily available. If a bearing runs dry on a motor having an undersized shaft, the bearing is immediately destroyed and the rotating element rubs on the polepieces. This may overheat or otherwise damage the windings. In any case the bearing must be renewed before the motor can be put into service.

The windings should be substantially constructed and well impregnated with insulating compound. The ends of the coils extending from the slots should be braced against movement caused by magnetic stresses. Any movement in the end windings causes stress in the insulation where the coils come out of the slots that will form cracks and allow moisture and dirt to enter. This, in time, will lead to an insulation failure if not prevented by good maintenance.

Too frequently the fact is overlooked that there is something to pay for upkeep after a motor and controller have been installed. This cost is generally in inverse ratio to the investment in quality of equipment and sound engineering put into the installation. When the job has been well engineered and high-grade equipment selected and well installed, maintenance costs will be low. Equipment not suited to its work and poorly installed means high maintenance cost, service interruptions, and reduced production with increased unit cost.

The amount and kind of protection required by electrical equipment depends upon conditions. In clean surroundings, the chief consideration is to protect the equipment against overload and operating abuses. Overfusing or setting circuit breakers to trip at too high a load is frequently the cause of a machine's roasting out. If a motor is properly protected and is blowing fuses or tripping the circuit breaker, the cure for the trouble is not a large fuse or a higher setting of the breaker. The cause of the overload should be located and removed. If it is due to peak

For most applications the mica should be undercut in the commutator

For maintenance costs to be low, the equipment must be suited to the application and be properly installed. And then a well executed inspection system will result in practically 100 per cent reliability

Instruments should be a part of inspection and maintenance equipment

loads of short duration, a time limit should be provided on the protective equipment to allow the motor to carry peak loads within its thermal capacity. The correct remedy for the trouble is much cheaper than roasting out the motor.

Polyphase alternating-current motors operating near their rated loads with one phase open are likely to have their windings damaged by overheating if they are not protected against single-phase operation. Many motors have had their windings damaged from this cause that need not have been had single-phase protection been provided.

Mechanical protection may be of equal importance in severe applications. In all cases the windings should be safeguarded against oil from the bearings. If the bearings are open at the ends they should be closed by felt washers. Where dust, moisture, and fumes are present, and open motors are used, they must be shielded by a covering. Better still, motors might be selected that have frames designed for the conditions under which they operate. When motors operate in very damp places, if their coverings are not moisture proof, they can be kept dry when not in operation by placing a lamp inside the covering.

Careful attention should be given to locating the motor and control equipment so that it can be maintained without danger of injury to the attendant. Installing a motor in a dark corner, difficult of access, just to save a little space, generally means paying high rental for that space by reason of increased maintenance and other costs.

Regular and systematic inspection must be part of any maintenance program. If equipment is regularly inspected, kept clean, and lubricated there should be little repair work necessary unless operating conditions are unusually severe. In many plants where an inspection and cleaning program is rigidly followed repair costs are negligible and shutdowns are virtually unknown.

Cleanliness is the first requisite of any maintenance program. When the machines are cleaned at regular intervals, conditions that might have led to failure of the insulation are prevented from arising and little faults that might have induced serious trouble are detected and repaired before they cause a shutdown and perhaps serious damage to the windings. Where a compressed-air supply is not available at the motor for blowing dirt out of the windings, a portable motor-driven blower is a convenient tool for doing this work. When motors are being cleaned the lubrication of the bearings should be checked. More attention has to be given to open-sleeve bearings than to those that are closed or to anti-friction types. Where once in three months may be often enough to check the lubrication of inclosed sleeve and anti-friction bearings, the open-sleeve type should be given attention every one or two weeks to see if the oil rings are running freely and if the oil is at the proper level. At least once a year the oil should be drained from the bearings, after which they should be washed out with kerosene and filled to the proper level with new oil. In lubricating motors, care must be exercised to fill the bearings to the proper level. If too much oil is used it is likely to get on to the windings and damage the insulation. It has been found that as high as 90 per cent of winding failures are caused by excess oil.

Once or twice a year, depending upon the conditions under which machines operate, the windings should be given a good coat of insulating varnish. If the machines are small and can be taken out of service for a sufficient time, they should first be baked, the varnish applied, and then baked again. On medium- and large-sized machines a coat of air-drying varnish, sprayed on, serves the purpose of closing the insulation against moisture and dirt. Intelligent use of insulating varnishes will go a long way toward insuring 100 per cent service from equipment.

On direct-current machines the commutator must be kept clean and smooth; in most applications the mica should be undercut. There are several types of grinding tools available for resurfacing commutators. Some of

these are of the rotating type, and others are held against the comutator at rest. The latter is similar to the handstones in wide use. Although a riffler file or a piece of nacksaw blade may be used to undercut mica, power-driven undercutting tools will do the job better and more quickly.

Periodically, after the mica is undercut, the slots should be cleaned out. The time between cleanings will vary with operating conditions. Where moisture and vapors are present the cleaning will have to be more frequent than where the conditions are dry and clean. In the former it may be necessary to clean the slots once a week, where in the latter every three months may be sufficient. Compounds are available for filling the slots of undercut commutators where frequent cleaning is necessary.

The brushes must be suited to the machine and service; they must be properly fitted to the commutator and move freely in the holders. If these features are given proper attention little trouble should be experienced if the machine is in otherwise good condition.

Instruments should form a part of every inspection and maintenance equipment. Alternating-current motors and controllers are seriously affected by voltage changes. If operation of these motors is not satisfactory the voltage should be checked to see if it is near normal and if the different phases are balanced. Current readings should be taken on each phase to determine whether all are equally loaded. To check the load on motors a recording watt meter is preferable. It can be connected in the circuit and left on long enough to obtain a sufficient indication of actual load conditions. Periodic load tests and a record of them will show any change in loading of the motors. On certain applications the wear of bearings or other parts may cause a large increase in the load. If such conditions are found when they first develop, large power losses can be prevented and the trouble corrected before the motor is overloaded and the windings overheated.

Another useful instrument, and one that is finding increasing use, is a megohm meter, used to measure equipment's insulation resistance. A periodic check on insulation resistance is a good guide to the condition of windings. A gradual decreasing of resistance shows that insulation is weakening in some part. Knowledge of this allows of taking proper steps to correct the fault before a failure occurs.

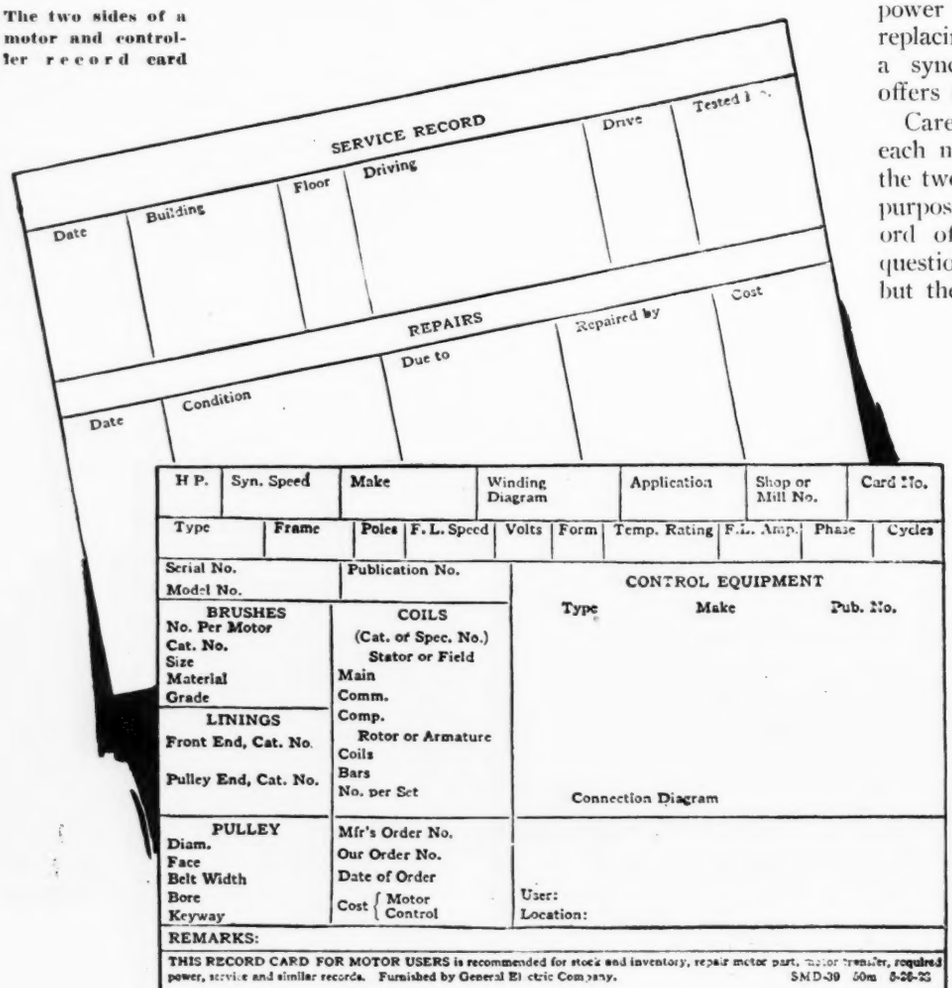
During the last five years many improvements have been made in alternating-current motors. Induction motors are available in any size for starting on full voltage. These motors require very simple starting equipment, low in first cost and easy to maintain. They also have a better efficiency than earlier types, and their construction is such that they are more reliable in operation. Synchronous motors have been developed to where they have starting characteristics comparable with induction machines.

These developments frequently make it desirable, when an old-type motor has to be rewound, to replace it by a new machine. If the old motor is not well suited to its drive, replacing it with a new one allows of correcting this condition, and in addition a more simple and efficient machine can be obtained. If the power factor of the system is low, replacing an old induction motor with a synchronous machine frequently offers a remedy.

Careful records should be kept of each motor. The forms shown are the two sides of a card used for this purpose. Not only does such a record offer a handy reference when questions arise concerning a motor, but the repair costs indicate the expense of keeping the motor in service. If the costs are running too high the cause can be investigated, and where irremediable it may prove cheaper to install a new motor than to keep the old one in service. To make such a decision intelligently requires a complete record of a motor's operation.

One of the strongest arguments for good inspection and maintenance methods and comprehensive records is that the most intelligently operated plants have the lowest operating costs. This is very largely because the little defects are located and corrected before they cause shutdowns and expensive repairs.

The two sides of a motor and controller record card



NEWS of the FIELD

Power Engineers to Hold 48th Convention in Cleveland Auditorium, Sept. 8-13

Interesting addressess, discussions of problems, power and mechanical exhibition, plant trips and outdoor recreation will enliven program

ANTICIPATING a lively business and entertainment program, the members of the National Association of Power Engineers will gather at Cleveland, Ohio, from Sept. 8 to 13 for their 48th annual convention. Besides delegates officially representing the many N.A.P.E. branches throughout the country, a large attendance of individual members, friends, and manufacturers' representatives is expected. The Statler and Hollenden Hotels have been selected as convention headquarters, but the business sessions and exhibition will be held at the Cleveland Public Auditorium.

Several business sessions and many entertainment features are scheduled on the tentative program. Addresses by national officers and prominent men, committee reports, and discussions are features of the meetings, while trips, social functions, and outdoor sports will provide enlivening recreation. There will be ample time to take in the scenic beauties, historical points of interest, and some of the leading industrial and power plants in and around Cleveland. Of particular interest to power engineers are the 67,000-hp. steam plant owned and operated by the city, the large central stations of the Cleveland Electric Illuminating Company, and Nela Park where the enormous laboratories of the National Lamp Works of the General Electric Company is located.

During the entire five days of the meeting the 1930 Power and Mechanical Exposition will be held in conjunction with the convention by the National Exhibitors' Association at the Cleveland Public Auditorium. This auditorium has been called one of the greatest structures of its kind in America. It is designed in the Italian Renaissance style of architecture and is of fireproof steel construction. The interior is faced with marble, tile, and decorative plaster, battleship gray being the predominating color. The main auditorium is artificially illuminated by a flood of soft light diffused through a field of glass panels in the ceiling. The whole effect is a softness and warmth unusual in buildings of such immense proportions. The auditorium's acoustics have been declared perfect.

A pipe organ costing $100,000 and said to be the finest in the United States in the matter of variety and scope of tone is part of the building's equipment. It has 10,010 pipes and 150 direct speaking stops. The echo organ is located in the rear of the auditorium, 300 ft. from the console.

The stage is one of the largest in America, being 104 ft. wide and 56 ft. deep. It has an opening 72 ft. wide surmounted by a high arch.

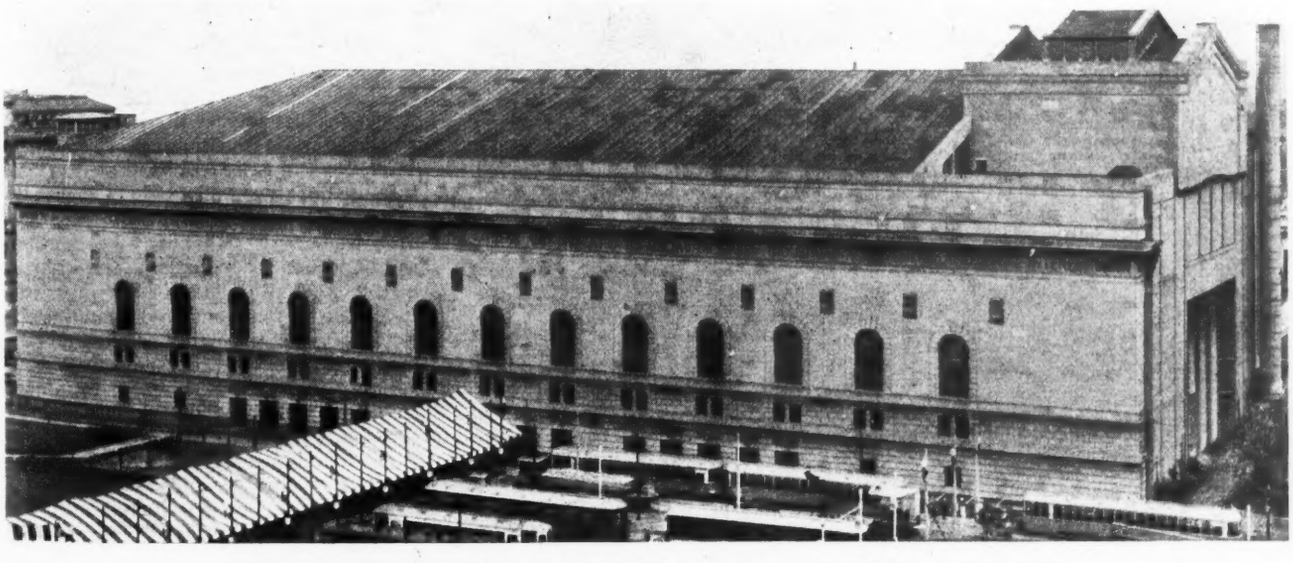
Toledo Edison Ties in Heating With Power

First units in a central steam heating system for the business district of Toledo, Ohio, are being completed by the Toledo Edison Company, in a program which will involve a total investment of approximately $750,000 and the service on the lines now being laid will be available Sept. 15.

Approximately 4,000 ft. of mains is being laid this year in Toledo as the first portion of a system that calls for 15,000 ft. of mains and 5,000 ft. of service lines. The steam will be generated at the Water Street power station, which is used as a stand-by for peak loads of electric power.

Surveys by engineers of the company showed that much more economical operation for both power and heating could be obtained by the development of the new central heating system.

The new Toledo Edison heating system will have a capacity of 1,500,000,000 lb. annually and is built to deliver the steam at 150 lb. pressure, although lower pressures will be used at the start.



Cleveland Public Auditorium where N.A.P.E. convention and exhibition will be held

Union Carbide & Carbon Corp. Building 200,000-Hp. Steam and Hydro Project

CONSTRUCTION work is now under way on new hydro-electric and steam power plant developments of subsidiary companies of Union Carbide & Carbon Corporation, in the vicinity of Hawks Nest, Gauley Junction and Boncar, W. Va. The total installed capacity of the two plants will be about 200,000 hp. Power output will be utilized by the proposed industrial plant of Electro Metallurgical Company at Boncar.

The hydro-electric power development is being built by New-Kanawha Power Company and is located on the New River, between Hawks Nest and Gauley Junction. The dam will be about 826 ft. long between abutments and will raise the water of New River about 60 ft. above low stage at the dam. From the pool above the dam water will be diverted into penstocks by an intake and tunnel, the tunnel being about 16,250 ft. in length and 30 ft. in diameter. At about mid-length the tunnel will be provided with an intermediate surge basin and at its lower end with a surge tank of large dimensions.

The power house will contain four units, each rated at 35,000 hp. From the power house a transmission line will run a distance of about six miles to the industrial plant at Boncar, where a power connection will be made with the proposed steam-electric power plant. The contract for the construction of the dam, tunnel, and power house was let to Rinehart & Dennis Company, and the entire development is expected to be ready for operation by March 13, 1932.

The steam-electric power plant is being built by West Virginia Hydro-Electric Company on the Kanawha River immediately adjacent to the site of the industrial plant at Boncar. It will consist of two turbine-generator units, each with a capacity of 22,500 kw. This plant will even out the irregularities of the power supply of the hydro-electric plant. Contract for the design and construction of the steam plant was let to Ford, Bacon & Davis, and it is expected that it will be finished about July 1, 1931.

The hydro-electric and steam plants are expected to provide an average combined annual output of about 120,000 horsepower.

O. M. Jones, chief engineer of New-Kanawha Power Company, who is located at Glen Ferris, W. Va., is in local charge of the hydro and steam plant installations for L. H. Davis, of New York, vice-president of New-Kanawha Power Company and West Virginia Hydro-Electric Company. E. H. Mangen is resident engineer in charge of the industrial plant installation for H. L. Noyes, chief engineer of Electro Metallurgical Company, who is located at Niagara Falls, N. Y.

Opinion Believed Against Recess Appointments

While nothing in the language of the amendment to the Water Power Act precludes the President from making recess appointments, there is some ground for believing that those who formulated the bill intended to provide against such action. This is understood to be the purport of the Attorney General's opinion submitted recently in reply to President Hoover's request for an interpretation of that phase of the act.

At this writing the text of the opinion has not been made public and apparently it has not been decided whether to give recess appointments to the three nominees whose names were not acted upon by the Senate before adjournment, or to have these men designated as special assistants to the three secretaries who form the Commission as now constituted. It is recognized that the confirmation of the nominees is likely to be made more difficult if they are called upon to serve prior to the convening of Congress.

Longest Stokers Ordered for Hudson Avenue

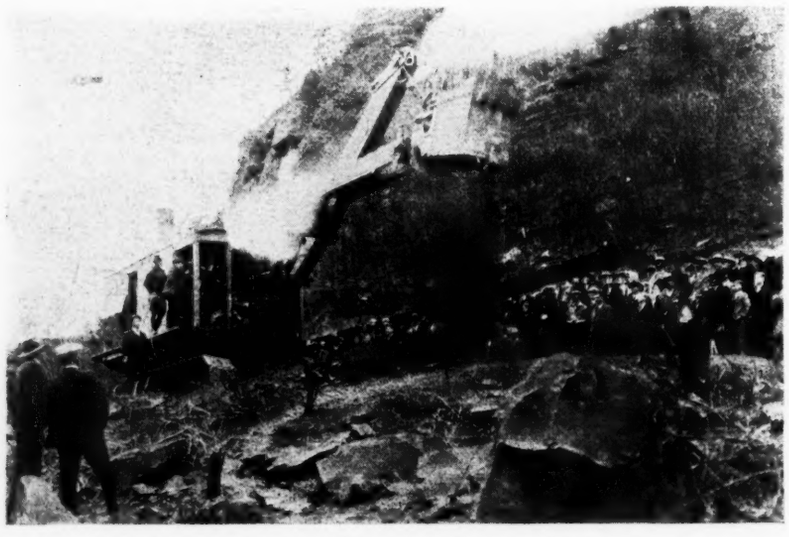
Contract for eight underfeed stokers for the new boiler units to be installed in the extension to the Hudson Avenue Station of the Brooklyn Edison Company has just been awarded to the American Engineering Company.

The stokers will be single units approximately 26½ ft. wide and 27 ft. deep. They will be the longest stokers ever manufactured, being 3 ft. more in length than any existing single-unit stokers in operation.

Some stokers in the past have been increased in size by widening the stoker, using more retorts. These stokers will be 15 retorts wide and 69 tuyères deep. The operating mechanism will be designed and made adequate for still more lengthening for future stokers of this type up to 81 tuyères deep.

Each stoker will be capable of burning approximately 60,000 lb. of coal per hour, developing 530,000 lb. of steam from each boiler per hour.

Control of the fuel-feeding mechanism will be by electric motors, and the coal-pusher mechanism will be adjustable over the entire width and length of each stoker. Adequate ash-disposal mechanism equipped with crusher rolls 36 in. in diameter will be provided.



Ground breaking ceremony at Hawks Nest, W. Va., as steam shovel turned the first bucketful of earth in the Union Carbide & Carbon Corporation's hydro-electric power development.

High-Pressure Symposium at A.C.S. Fall Meeting

Three divisions of the American Chemical Society will hold a joint symposium on the subject, "Industrial High-Pressure Reactions," at the fall meeting of the society in Cincinnati, Ohio, Sept. 8 to 12. Indicating the type of power services that may be required in the chemical industries, the subject matter covers the use of high pressures in chemical reactions and manufacturing process work. This session will be held at 2 o'clock on Tuesday, Sept. 9.

Other sessions of interest to power engineers are those of the Division of Gas and Fuel Chemistry, to be held on Wednesday afternoon and Thursday morning. Papers which will be presented at those sessions include:

"Flame Temperatures of Hydrocarbon Gases," by G. W. Jones, J. B. Friauf, and G. St. J. Perrott; "The Mecha-

nism of Combustion of Individual Particles of Solid Fuels," by Austin Gudmundsen and D. F. Smith; "The Slacking of Coal and Its Proper Interpretation," by S. W. Parr and D. R. Mitchell; and four studies in the development of Dakota lignite, by M. Larian, I. Lavine, C. A. Mann, A. W. Gauger, W. C. Eaton, G. A. Brady, C. F. Belcher, and E. E. Harris.

"Firability of Mid-Temperature Cokes," by S. W. Parr and D. R. Mitchell; "A Study of the Plastic State of Coal During Coking," by J. D. Davis and D. A. Wallace; "The Plastometer—A New Instrument for Measuring the Plastic Properties of Coal," by J. D. Davis.

250,000-Hp. Hydro Project Planned for Oregon

The California-Oregon Power Company has filed an application for license with the Federal Power Commission covering its proposed development on the North Umpqua and Clearwater Rivers in Douglass County, Ore. The proposed development consists of four projects, Rock Creek, Boundary, Toketee, and Lemolo, on the North Umpqua, and one unit on the Clearwater River. On the North Umpqua a fall of 2,648 ft. in the 57 miles of river between the mouth of Rock Creek and the mouth of Lake Creek will be utilized. On the Clearwater there is a fall of 1,450 ft. in the lower 7½ miles of the river. Water will be diverted into that steam from Watson, Fish, and Rough Creeks. There will be two power houses at the Lemolo site and at the Clearwater site. The primary power that thus will be made available is estimated at 117,915 hp. It is planned, however, to install 250,300 hp. The application for license is made in pursuance of a preliminary permit issued Aug. 15, 1927.

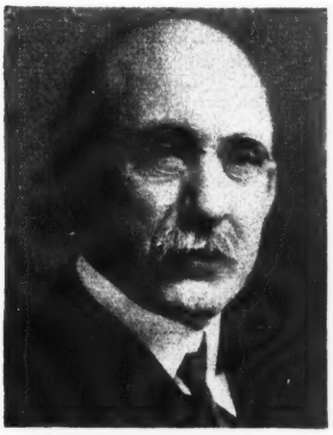
Shell Oil Company Places Large Motor Order

The Electric Machinery Manufacturing Company, Minneapolis, Minn., of which C. F. Henderson, San Francisco, Calif., is district representative, recently sold to the Shell Chemical Company, a subsidiary of the Shell Oil Company of San Francisco, the motor and control equipment for its new $3,000,000 plant. These motors and control will be used on the various compressors at the new Shell plant now under construction at Shell Point, near Pittsburg, Calif. The equipment consists of three 600-hp., 128-r.p.m. synchronous motors; four 1,000-hp., 128-r.p.m. synchronous motors; two 700-hp., 109-r.p.m. synchronous motors; two 100-kw., 1,200-r.p.m. synchronous motor-generator sets; one 24-panel switchboard; and two 200-hp., 600-r.p.m. synchronous motors.

Ira N. Hollis, Educator and Engineer, Dies

Ira Nelson Hollis, former president of Worcester Polytechnic Institute and a mechanical engineer of note, died Aug. 15 at his home in Cambridge, Mass. He had been ill only a short time.

Born at Mooresville, Ind., on March 7, 1856, Dr. Hollis was graduated from Louisville High School in 1872 and became an apprentice in a machine shop



Ira N. Hollis

building and repairing all kinds of engines. In 1874 he entered the United States Naval Academy, graduating from there with the Class of 1878. He served as a naval engineer for five years, during which he worked under George W. Melville, then engineer-in-chief of the Bureau of Steam Engineering. In 1893 he resigned to become professor of engineering at Harvard University, where he remained until 1913. In that year he became president of Worcester Polytechnic Institute. He retired in 1925 and had since lived in Cambridge.

Dr. Hollis was president of the American Society of Mechanical Engineers in 1917 and an honorary member of that society. He was a fellow of the American Academy of Arts and Sciences, and a member of the American Society of Naval Engineers, American Society of Naval Architects and Marine Engineers, Boston Society of Civil Engineers and the Society for the Promotion of Engineering Education.

New Line for Utah

Definite decision to construct a new 44-kv. transmission line from a connection just north of Nephi, Utah to Delta, Utah, has been announced by H. B. Waters, general manager, Telluride Power Company. The line, which will tie in with the high voltage of the Utah Power & Light and the Telluride company's running from Sentaquin south into Sanpete County, will cross the Utah state highway about two miles north of Nephi.

News of Canada

Mid-year review of power development

HYDRO-ELECTRIC construction at present being carried on in Canada amounts to a greater figure than at any previous period in the history of the Dominion, according to a mid-year review issued by the Water Power Branch of the Department of the Interior covering up to June 30, 1930. Installations aggregating more than 1,680,000 hp. are under active development. Many of these comprise initial stages only, and when the plants have reached their ultimate designed capacities a further 2,000,000 hp. will be added to the total.

The review by provinces indicates development taking place in no less than 22 rivers scattered from one coast to the other. Some of these projects come into operation before the end of the present year and others in 1931 and 1932. Nine of the works at present under construction may be classed as really large developments. These major undertakings are on the Bridge and Stave rivers in British Columbia, the Winnipeg River in Manitoba, the Abitibi River in Ontario, the Ottawa River between the Provinces of Ontario and Quebec, and four rivers in the Province of Quebec.

In the Pacific Coast province the British Columbia Power Corporation accounts for two of the major developments. These are on the Stave and Bridge rivers, the former ultimately to have an installation of 188,000 hp., with a first unit of 47,000 hp. to be in operation this year. The Bridge River project will have an ultimate installation of 600,000 hp., with 80,000 hp. in operation in 1932. At the Jordan River station on Vancouver Island the same interests are installing a fourth unit of 18,000 hp., and on the mainland the Powell River Company has a new development under active construction on the Lois River planned for 44,000 hp., with initial installation of 22,000 hp. for 1931.

In Manitoba two large hydro-electric undertakings are under construction, both on the Winnipeg River. The Winnipeg Electric Company is developing the Seven Sister Falls site to have an ultimate installation of 225,000 hp. The city of Winnipeg is developing Slave Falls, where the designed capacity is 96,000 hp. in eight units, with two to operate in 1931.

There are also two outstanding developments under construction in Ontario, though one on the Ottawa River, an interprovincial stream, is shared with the Province of Quebec. The largest is on the Abitibi River, where construction has started on a 275,000-hp. development by the Hudson Bay Power Company. The second is at Chats Falls on the Ottawa, where the Ontario Hydro-Electric Power Commission is jointly carrying out a 224,000-hp.

undertaking with the Chats Falls Power Company. The hydro commission is also carrying to completion this year a 54,000-hp. development at Alexander Landing on the Nipigon River. The Canada Northern Power Company is bringing to completion a 13,000-hp. plant on the Montreal River.

Outstanding progress in hydro-electric development is indicated by the review in dealing with Quebec. The Beauharnois Company is energetically pressing construction on the St. Lawrence River, with the building of a power and ship canal fifteen miles in length and a 500,000-hp. station located at Lake St. Louis. The initial units, supplying 200,000 hp., are to be in operation by October, 1932. The Shawinigan Water & Power Company has commenced construction of the first of six developments on the Upper St. Maurice River, this undertaking at Rapide Blanc to have an initial installation of 160,000 hp. Another important project in Quebec is that at Chute-a-Caron, on the Saguenay River, where the Alcoa Power Company is making good progress with a hydro-electric undertaking the first stage of which will develop 260,000 hp. in four units, scheduled for operation early in 1931. Still another large undertaking is that of the James MacLaren Company at High Falls on the Lievre River, where a 90,000-hp. installation is practically completed. The ultimate capacity is to be 120,000 horse power.

Los Angeles Postpones Vote on Power Bond Issue

By vote of the Los Angeles Board of Water & Power Commissioners the proposed $19,000,000 bond issue to defray the expenses of a three-year construction program for power development will be placed on the ballot of the general election to be held Nov. 4, instead of on the ballot of the primary election to be held Aug. 26, as had originally been proposed. The board's recent action definitely postpones the bond election to the later date. For the construction proposed $31,000,000 will be required, but of that amount $12,000,000 is to be derived from power revenues.

Major items of the $31,000,000 construction program and their cost include: Two small power plants with a total capacity of 9,100 kw. in Owens Valley, and a 222-mile, 110-kv., steel-tower transmission line, $4,885,000; a 14,000-kw. third unit in plant No. 2 on the aqueduct, $925,000; additions and improvements to present generation and transmission system within the city, $3,725,000; new line and receiving substation, $3,075,000; additions to city distribution system, largely preparatory to distribution of Boulder Canyon power, $14,665,000; general equipment, warehouse, shops, etc., $1,200,000; Boulder Canyon transmission rights-of-way and attendant engineering, $2,525,000.

The committee, consisting of A. V. Guillou, assistant chief engineer of the California Railroad Commission; W. F. Durand, emeritus professor of mechanical engineering, Stanford University, and R. W. Sorensen, professor of electrical engineering, California Institute of Technology, which was retained by the Chamber of Commerce to investigate and report upon the proposed power program, has filed its report, and the board of directors of the chamber is expected to make its recommendations at an early date.

How's Business?

BUSINESS apparently hit a second bottom at the beginning of August, just a year after it went over the top in 1929. Since then little change, but indications that a slow up-pull has set in. Our index, with its final figures steady at 86.5% of normal for two weeks, rose a trifle to 86.9% this week. Industrial activity is still stagnant, but has reached resistance levels, despite the astonishing slackness of seasonal forward buying in wholesale lines. General trade, discounting drought doubts, has freshened since the first of the month. Commodity prices are decidedly firmer.

Whether business recovery from now on is to be slow or fast, only seasonal or permanent, is now chiefly a question of revival of individual initiative and aggressiveness which has been weakened in the past few months by repeated disappointment in miracles and by defeatist doctrines. Business may be slack, but business men are slacker.—*The Business Week*, Aug. 27.

Obituary

FRED D. LYON, engineer, of San Diego, Cal., died recently in that city. A native of Chicago, Mr. Lyon pursued his technical studies at the Armour Institute of Technology. From 1902 to 1905 he was engaged on the construction of the Fisk Street power house in Chicago, and for the next three years on construction of the Quarry power house. Then for a period of years Mr. Lyon engaged in various construction jobs, and in 1924 he was named general superintendent of the Cahokia power plant. Mr. Lyon has been active in the affairs of the American Institute of Electrical Engineers, being some few years ago chairman of the St. Louis section. He was also a member of the Western Society of Engineers, the Providence Engineering Society of Providence, R. I., and other engineering societies.

Personals

BYRON E. WHITE, chairman of the Hydraulic Power Committee of the Engineering National Section of the National Electric Light Association for the past two years, has been re-elected to that position for the year 1930-31.

LANDIS SHAW SMITH, district steam sales engineer with the Rochester Gas & Electric Corporation since 1920, was elected president of the National District Heating Association by the 200 members representing the major heating properties of the United States at the recent annual convention.

MATTHEW S. SLOAN, president of the New York Edison Company and associated companies, was recently elected a director and member of the finance committee of the Chrysler Corporation to succeed the late Nicholas F. Brady.

J. S. MOULTON, formerly executive engineer of the Great Western Power Company, is now attached to the Pacific Gas & Electric Company's executive offices as assisttant to A. EMORY WISHON, vice-president and assistant general manager of the latter company. Other changes in personnel occasioned by the recent merger of the companies include the appointment of W. G. B. EULER as engineer of operation for P. G. & E.'s properties in the San Francisco and East Bay divisions; the appointment of J. W. F. ARMSTRONG to the division of electric distribution and steam engineering; and the appointment of J. A. KOONTZ as an assistant engineer under J. P. JOLLYMAN, chief of the division of hydro-electric and transmission engineering.

ALLEN E. RANSOM, formerly connected with the Central States Power & Light Corporation of Dubuque, Iowa, has been appointed to the staff of the United States Engineers by the Secretary of War. Mr. Ransom has had a wide engineering experience with utility companies in the West and South.

W. S. LEE, president of the Duke Power interests, has just returned from a trip to Canada and expects to leave Charlotte, N. C., this week for a tour which will carry him to the Pacific Coast. He will attend the annual meeting of the Pacific Coast unit of the American Institute of Electrical Engineers in Portland, Ore. Mr. Lee is president of the organization and will visit many of its leaders in the different Western states.

FRANK T. POST was elected president, J. E. E. ROYER, general manager, and R. B. CHILDS, assistant general manager, respectively, of the Washington Water Power Company, Spokane, at a meeting of the board of trustees, held Aug. 4 in New York. The selections were made to fill two vacancies caused by death and the third a promotion.

Business Notes

QUIGLEY FURNACE SPECIALITIES COMPANIES, New York City, announces a change in the name of the company to QUIGLEY COMPANY, INC., owing to the rapid and broad development of its products during the last few years. Originally this company dealt in furnace specialties only, but in recent years has engaged in the manufacture and marketing of a number of additional products used in a wide variety of industries.

BABCOCK & WILCOX COMPANY, New York City, has appointed Mayer & Oswald, Inc., 332 South La Salle St., Chicago, Ill., as exclusive distributors of No. 80 refractory cements and plastics in the Chicago territory.

CHICAGO PUMP COMPANY, Chicago, Ill., announces the addition of H. G. Ragan to its list of representatives. Mr. Ragan has offices in the Brandeis Theater Building, Omaha, Neb., and will handle the line in that territory.

LINK-BELT COMPANY, Chicago, Ill., announces the appointment of William Piez as European correspondent to give closer contact to the company's agents and customers in Europe, the British Isles and North Africa. Mr. Piez, a brother of Charles Piez who is chairman of the company, will establish headquarters at Hotel Lutetia, 43 Boulevard Raspail, Paris, France.

ROSEDALE FOUNDRY & MACHINE COMPANY, Pittsburgh, Pa., is announcing the Playford stoker under the name of the Playford Stoker Company, Division of the Rosedale Foundry & Machine Company of Pittsburgh, Pa.

NEILAN COMPANY, LTD., Los Angeles, Calif., has opened a branch office in San Francisco at 16 Avila Road. William S. Waldrip, who has been with the firm for several years, will be in charge of the new branch.

MINNEAPOLIS - HONEYWELL REGULATOR COMPANY, Minneapolis, Minn., will sponsor a thirteen-week radio program by the Minneapolis Symphony Orchestra over the Columbia Broadcasting System of 22 stations. The first of these weekly broadcasts will commence on Monday, Sept. 8.

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, East Pittsburgh, Pa., announces the appointment of T. R. Langan as assistant Northeastern district manager of the company. Mr. Langan has been with the Westinghouse organization for more than twenty years. He will make his headquarters at New York.

ALLEN - SHERMAN - HOFF COMPANY, Philadelphia, Pa., has appointed as representatives F. S. Heward, New Berks Building, Montreal, Que., and J. P. McRea, Colonial Bank Building, 11 King St., West, Toronto, Ont., Canada.

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COMING CONVENTIONS

American Society of Mechanical Engineers. Fall meeting at French Lick Springs, Ind., Oct. 13-17. Annual meeting in New York City, Dec. 1-5. Secretary, Calvin Rice, 33 West 39th St., New York City.

American Institute of Electrical Engineers. Annual Pacific Coast convention at Portland, Ore., Sept. 2-5. District meeting at Philadelphia, Pa., Oct. 13-15. District meeting at Louisville, Ky., Nov. 19-22. Secretary, F. L. Hutchinson, 33 West 39th St., New York City.

American Welding Society. Fall meeting at the Congress Hotel, Chicago, Ill., Sept. 22-26. Secretary, M. M. Kelly, 33 West 39th St., New York City.

Midwest Power Engineering Conference and Exhibition. Fifth meeting in Chicago, Ill., Feb. 10-13, 1931. Secretary, George E. Pfisterer, 308 West Washington St., Chicago, Ill.

National Association of Power Engineers. Annual convention and exhibition of power machinery at the Cleveland Auditorium, Cleveland, Ohio, Sept. 8-13. Secretary, Fred W. Raven, 417 South Dearborn St., Chicago, Ill.

National Association of Practical Refrigerating Engineers. Annual convention and exhibition at the Hotel Peabody, Memphis, Tenn., Nov. 11-14. Secretary, Edward H. Fox, 5707 West Lake St., Chicago, Ill.

National Power Show. Grand Central Palace, New York City, Dec. 1-6. Manager, Charles F. Roth, Grand Central Palace, New York City.

Society of Industrial Engineers. Seventeenth national convention at the Mayflower Hotel, Washington, D. C., Oct. 15-17. Secretary, George C. Dent, 205 West Wacker Drive, Chicago, Ill.

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Trade Catalogs

VALVES—The MJL duplex control valve unit, for controlling two separate fluids in a certain definite and predetermined relation to one another, is described and illustrated in Bulletin No. 206 of Morey & Jones, Ltd., 922 South Hemlock St., Los Angeles, Calif.

EVAPORATORS—Helpful information on the elimination of boiler scale is contained in illustrated Bulletin No. 361 just issued by the Griscom-Russell Company, 285 Madison Ave., New York City. This bulletin fully discusses the functions, applications and advantages of evaporators for distilling boiler-feed make-up water. One topic of particular interest is the recently developed "Reducing Valve Evaporator System" which permits the economical application of evaporators to industrial plants requiring considerable steam for process work.

SWITCHES—The Delta-Star Electric Company, 2400 Block, Fulton St., Chicago, Ill., has issued a new bulletin, No. 39-A, describing vertical-break, gang-operated switches for line and outdoor substation service. Complete dimensions and installation data are given.

OIL BURNERS—The Coen system of mechanical oil burning in stationary power plants is fully described and illustrated in Bulletin 17 on mechanical oil burners, recently issued by the Coen Company, Executive Offices Story Building, Los Angeles, Calif. Other recent publications of the company include: Bulletin 19 on gas burners and combination gas and oil burners, Bulletin 14 on duplex strainers, and Bulletin 15 on oil heaters of the film type, all steel and cleanable.

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Fuel Prices

COAL

The following table shows the trend of the spot steam market in various coals, f.o.b. mines; mine run, except Pittsburgh gas slack:

Bituminous (Net Tons)	At Mine, for Shipment to	Price per Ton
Navy Standard	New York	$2.10 @ $2.30
Kanawha	Cincinnati	1.10 @ 1.35
Smokeless	Cincinnati	1.75 @ 2.00
Smokeless	Chicago	2.00 @ 2.25
West Kentucky	Louisville	.85 @ 1.25
Steam	Pittsburgh	1.50 @ 1.60
Gas Slack	Pittsburgh	.90 @ 1.10
Big Seam	Birmingham	1.60 @ 1.75

Anthracite (Gross Tons)	At Mine, for Shipment to	Price per Ton
Buckwheat	New York	$3.00
Barley	New York	1.15 @ 1.50

FUEL OIL

New York—Aug. 21, f.o.b. Bayonne, N. J., 28@34 deg., Baumé, industrial use, tank-car lots, 4.75c.@5.25c. per gal.; f.o.b. Bayway, 36@40 deg., furnace, tank-car lots, 6c.@6.25c. per gal.

St. Louis—Aug. 13, tank-car lots, f.o.b. St. Louis, 24@26 deg., $1.345 per bbl., or 42 gal.; 26@28 deg., $1.445 per bbl.; 28@30 deg., $1.520 per bbl.; 30@32 deg. $1.620 per bbl.; 32@36 deg., gas oil, 3.901c. per gal.; 38@40 deg., distillate, 4.651c. per gal.

Pittsburgh—Aug. 13, f.o.b. local refinery, 34@36 deg., fuel oil, 3.12½c. per gal.; 36@40 deg., 3.25c.

Philadelphia—Aug. 14, 13@19 deg., $1.05@$1.10 per bbl. or 42 gal.; 18 deg. plus, $1.475@$1.525 per bbl.; 23@27 deg., $2.00@$2.05 per bbl.

Cincinnati — Aug. 19, tank-car lots, f.o.b. local refinery, 24@26 deg. Baumé, 5.25c. per gal.; 26@30 deg., 5.5c. per gal.; 30@32 deg., 5.75c. per gal.

Chicago—Aug. 13, tank-car lots, f.o.b. Oklahoma, freight to Chicago, 90c. per bbl. or 42 gal.; 22@26 deg., 65c. per bbl.; 26@30 deg., 75c. per bbl.; 30@32 deg., $0.90 per bbl.

Boston—Aug. 18, tank-car lots, f.o.b., 12@14 deg., Baumé, 3.33c. per gal.; 28@32 deg., 5c. per gal.

Dallas—Aug. 16, f.o.b. local refinery 26@30 deg., $1.10 per bbl. or 42 gallons.

New Plant Construction

COMPILED BY THE MCGRAW-HILL BUSINESS NEWS DEPARTMENT, WHICH IS PREPARED TO FURNISH A MORE COMPLETE DAILY SERVICE TO THOSE WHO WISH IT

Ark., Carver—Ozark Reduction Co., of Jasper, c/o G. N. Peavy, Little Rock, had plans prepared for the construction of a hydro-electric power plant and dam on the Buffalo River here, 10 mi. east of Jasper to form lake about 10 mi. square. Estimated cost $1,000,000. F. E. Hatch, is consulting engineer.

Ark., Pine Bluff — White River Power Co., H. C. Couch, Pres., plans the construction of a hydro-electric plant and three dams on the White River, one dam will be 2,200 ft. long and 175 ft. high and will create a lake thirty miles long. Estimated cost approximately $25,000,000. Phoenix Utility Co., 2 Rector St., New York, N. Y., are engineers.

Ark., Paragould—City plans an election Sept. 21 to vote $125,000 bonds for the construction of a municipal power and light plant. Estimated cost $125,000.

Calif., Oakland—East Bay Municipal Utility Dist., received lowest bid for spare parts for Pardee power plant from General Electric Co., Russ Bldg., San Francisco.

Calif., Petaluma—Petaluma Ice & Cold Storage Co., awarded contract for the construction of a 40 ton ice and cold storage plant to Gay Engineering Corp., 2650 Santa Fe St., Los Angeles. Estimated cost $42,500.

Calif., Santa Cruz—Coast Ice & Cold Storage Co., E. E. Huddleson, Pres., plans the construction of an ice and cold storage plant. Estimated cost $40,000.

Colo., Paonia — Oliver Power Co., awarded contract for the construction of a power plant to Phoenix Utility Co., 2 Rector St., New York, N. Y. Estimated cost $250,000.

Conn., New London—Connecticut College for Women, Mohegan Ave., awarded contract for the construction of a 1 story, 45 x 70 ft. boiler house to John Mondelci & Co., 225 Coleman St. Estimated cost $41,500.

Conn., Newtown—State of Connecticut, awarded contract for the construction of a hospital for Insane on Mile Hill to C. Abedessa & Bros. Inc., 159 Winthrop Ave. Steam heating and ventilation systems, awarded to Libby & Blinn Inc., 135 Shelton St., Hartford. Estimated cost $1,750,000.

Fla., Tallahassee—State Bd. of Control, awarded contract for the construction of a central heating plant at Florida State College for Women to J. M. Raymond Construction Co., Jacksonville. $46,458. Contract let for electrical equipment.

Kan., Holton—City, J. A. Pomeroy, Clk., awarded contract for a 600 kw. engine for power plant to Worthington Pump & Machinery Co., Dwight Bldg., Kansas City, Mo. $44,000.

Kan., Leavenworth—St. Mary's Academy, had plans prepared for the construction of a boiler house including stack, 155 ft. high. M. Carroll, 713 Linwood Blvd., Kansas City, Mo., is engineer.

Ky., Louisville—Waverly Hills Sanitorium, plans additions to hospital including power plant, etc. Estimated total cost $465,000. Architect not selected.

Mass., Boston—Institutions Dept., plans extensions and improvements to power plant at Long Island Hospital. Estimated cost $50,000. Private plans.

Mass., Cambridge (Boston P.O.)—Cambridge Industrial Trust, 25 State St., awarded contract for the construction of a 1 story power house to S. C. Sperry Co., 288 Main St., Cambridge. Estimated cost $40,000.

Mass., Cambridge (br. Boston P. O.)—Harvard University, A. L. Lowell, Pres., awarded contract for the construction of a switch house on Winthrop St., to Hegeman-Harris Co. Inc., 185 Devonshire St., Boston. Estimated cost $40,000 including equipment.

Mo., Chillicothe—Bd. of Public Works, W. J. Wiley, Secy., awarded contract for a 1500 kw. turbo-generator unit surface condenser and accessories, etc., to Elliott Co., Fairfax Bldg., Kansas City.

Mo., St. Louis—Forest Park Highland Exhibition & Amusement Co., B. G. Brinkman, Pres., 5600 Oakland Ave., Tulsa, Okla., plans the construction of an ice rink here. Estimated cost $138,000. Work will be done under the supervision of R. C. McCoy, engineer.

N. J., Hackensack—Bd. of Chosen Freeholders, Court House, is having preliminary plans prepared for the construction of a 6 story hall of records building including steam heating system, etc. at Main and Hudson Sts. Estimated cost $1,200,000. E. L. Telton and W. F. Schwanewede, 420 Lexington Ave., New York, N. Y., are architects.

N. J., Skillman — Dept. of Institutions & Agencies, State Office Bldg., Trenton, received lowest bid for the construction of a 2 story, 70 x 90 ft. power house at State Village for Epileptics here from A. Christensen, 80 Broad St., Elizabeth. $99,800.

O., Cleveland — Cleveland Terminal Building Co., R. Sharp, Gen. Mgr., Terminal Tower, will soon award contract for the construction of a 12 story department store at 2030 Ontario St. Estimated cost $9,500,000. Graham, Anderson Probst & White, Railway Exchange Bldg., Chicago, Ill., are architects.

Okla., Vinita — City had preliminary plans made for the construction of a municipal light plant. Estimated cost $100,000. F. C. Cornell, is engineer.

Ore., Eugene—Eugene Water Board, awarded contract for condenser to C. H. Wheeler & Co., $23,000, and brick work for boiler to Young-Hartman $12,366 in connection with steam electric plant now under construction.

Pa., Ford City—City had preliminary surveys made for electric light plant in Armstrong Co. Burns & McDonnell Engineering Co., Interstate Bldg., Kansas City, Mo., are consulting engineers.

R. I., Melville—Bureau of Yards & Docks, Navy Dept., Washington, D. C., awarded contract for the construction of a power plant at Naval Fuel Depot here to Coleman Construction Co., 86 Weybosset St., Providence.

Tex., Kingsland—Emery, Peck & Rockwood Development Co., 208 South LaSalle St., Chicago, Ill., plans the construction of two power dams on the Colorado River. One at Old Hamilton site six mi. above Kingsland, will be a low dam for generating power; second near Bluffton, will create a reservoir 40 mi. long. Estimated total cost $2,500,000. Fargo Engineering Co., Jackson, Mich., is engineer.

Tex., Schertz—U. S. Government, c/o A. W. Parker, Constructing Quartermaster, received lowest bid for the construction of a 180 x 280 ft. post exchange building including cold storage plant at Randolph field near San Antonio, from West & Jensen, Second National Bank Bldg., Houston, $62,539. Also officers mess hall, etc., from Brennan Co., Dallas. $63,280.

Wash., Anacortes—City will receive bids until Sept. 5 for the construction of a waterworks system including pump house, 30 in. in diameter and 16 ft. deep. Estimated cost $400,000. W. C. Morse & Co., Smith Tower, are engineers.

Ontario—Ontario Power Service Corp., subsidiary of Abitibi Power & Paper Co., Northern Ontario Bldg., Toronto, awarded contract for the construction of a hydro-electric development on the Abitibi River near Cochrane to Dominion Construction Co., Reford Bldg., Toronto. Estimated cost approximately $20,000,000.

Equipment Wanted

Air Compressors—Montreal, Que.—City plans to purchase two air compressors.

Boiler—Pasadena, Calif.—City will receive bids until Sept. 4 for furnishing and installing boiler for municipal light and power plant. Former contract rescinded.

Gas Burning Equipment—San Antonio, Tex.—M. A. Quinn, Post Quartermaster, San Antonio, is receiving bids for furnishing and installing gas burning equipment in heating boilers at Fort Sam Houston.

Generator—South Boston, Mass.—Peninsular Family Laundry, 27 Boston St., 75 to 100 kva. generator, a.c. direct connected, 3 ph., 60 cycle, 220 v.

Pumping Equipment—Youngstown, O.—Bd. of Directors, Mahoning Valley Sanitary District, 901 City Bank Bldg., will receive bids until Sept. 19 for motor driven pumping equipment and auxiliary electrical equipment for Meander Creek water purification and pump works.

Pump Units—Washington, D. C.—A. L. Flint, General Purchasing Officer of the Panama Canal, will receive bids until Aug. 28 for pump units, etc.

Pumping Unit, Etc.—Barstow, Tex.—Sutherlin, Barry & Co., Canal Bank Bldg., New Orleans, La., plans to purchase pumping unit, etc. for proposed waterworks system. Estimated cost $45,000.

Regulator, Pump, Etc.—Woodville, Miss.—Bd. of Aldermen, will receive bids until Sept. 2 for one voltage regulator connected to exciter of 5 kw. and 7½ kw. 125 v., also 100 to 500 g.p.m. pump direct connected to a.c. motor.

Switchboards, Generators, Transformers, Etc.—New Orleans, La.—Sewerage & Water Board, G. G. Earl, Gen. Supt., will receive bids until Oct. 1 for Cont. 117-D truck type switchboards, motor generators, transformers and accessories for Drainage stations 3 and 7.

Transformers—Binghamton, N. Y.—Dept. of Mental Hygiene, State Office Bldg., Albany, will receive bids until Sept. 10 for new transformers and cables at Binghamton State Hospital here.

Turbine—Kansas City, Mo.—Corn Products Refining Co., 608 Brokers Bldg., plans to purchase a 4,000 kw. steam turbine.

Industrial Projects

Calif., South San Francisco—Seattle Chain Mfg. Co., 6921 East Marginal Way, Seattle, Wash., awarded contract for the construction of a 1 story factory here to The Austin Co. of California, Ray Bldg., Oakland. Estimated cost $40,000.

Conn., Hartford — Terry Steam Turbine Co., Windsor St., awarded contract for a 2 story addition to factory, to Bartlett-Brainard Co., 252 Asylum St. Estimated cost including equipment $40,000.

Conn., Norwich—City Gas & Electric Dept., 34 Shetuck St., awarded contract for the construction of a gas and electric distribution plant on North Main St. to P. F. Sweeney, 25 Chestnut St. Estimated cost $40,000.

Ind., Evansville—Metal Process Co., awarded contract for the construction of a factory to M. J. Hoffman Construction Co. Estimated cost $250,000. Two overhead electric cranes, etc., will be installed.

Ind., Evansville—Mead-Johnson Co., awarded contract for the construction of a factory on South St. Joseph St., to C. Kanzler & Sons, 500 Furniture Bldg. Estimated cost $40,000.

Ind., Muncie—Central Indiana Co., E. A. Angley, Gen. Mgr., plans the construction of an artificial gas plant. Estimated cost $1,000,000. Work by owners forces, also to expend $1,000,000 for additional gas production machinery and equipment.

Me., Gardner—Hollingsworth & Whitney Co., is having preliminary plans prepared for addition and alterations to boiler house. Estimated cost $40,000.

Mass., Everett—(Br. Boston)—Mystic Iron Works, 250 Stuart St., Boston, awarded contract for addition and alterations to boiler house on Dexter St. to Koppers Construction Co., Kopper Bldg., Pittsburgh, Pa. Estimated cost $40,000.

N. J., Camden—Continental Can Co., c/o Francesco & Jacobus, 511 5th Ave., New York, N. Y., Archts., plans the construction of a 5 or 7 story, 129 x 339 ft. factory at Arch and Second Sts. here.

N. J., East Rutherford—East Rutherford Syringe Co., 75 Mozart St., is having plans prepared for the construction of a 2 story factory at 54 Mozart St. Estimated cost $40,000. J. T. Camlet, 26 Piaget Ave., Clifton, is architect.

N. Y., Syracuse—Syracuse Lighting Co., 421 South Warren St., plans the construction of a new gas plant to replace present plant. Gas storage holder, 10,000,000 cu.ft. capacity, generating capacity to be increased from 6,000,000 to 16,000,000 cu.ft. daily. Estimated cost $1,000,000.

O., Cleveland—Allied Oil Co., F. R. Newman, Secy.-Treas., 1021 Guardian Bldg., awarded contract for a group of buildings including, 24 x 50 ft. boiler house, 24 x 40 ft. pump house and 20 x 20 ft office, etc. on East 40th St., to Masters & Mullen Construction Co., Rose Bldg. Estimated cost $40,000.

O., Cleveland—Cleveland Provision Co., H. A. Schanz, Pres. and Treas., 2527 Canal Rd., plans the construction of a 2 story packing plant at 3378 West 65th St. Estimated cost $200,000. H. B. Henschein, 1637 Prairie Ave., Chicago, Ill., is engineer.

O., Cleveland — Cleveland Steel Products Co., 7300 Madison Ave., manufacturers of oil burners, had plans prepared for the construction of a 1 story, 78 x 90 ft. factory. Estimated cost $40,000. G. S. Rider Co., Marshall Bldg., is architect.

O., Massillon — Corundite Refractories Inc., awarded contract for the construction of a 1 story factory to house new kiln to T. L. Pixon Co., Pittsburgh, Pa. Estimated cost $50,000.

Tex., Laredo—H. P. Henderson, 522 5th Ave., New York, N. Y. & Associates, plan the construction of a smelting plant here, to smelt antimony to be brought in from mines in Mexico. Plans include eleven buildings. Estimated cost $125,000. J. P. Harper, San Diego, Calif., is mining engineer.

Wash., Seattle—American Can Co., Elliott and Vine Sts., awarded contract for the construction of a 2 story warehouse to A. W. Quist & Co., Hoge Bldg. Estimated cost $1,000,000.